Get ready for July 22's great Asian eclipse p. 56

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July 2009

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How dying stars bring new planets to life

A doomed star can awaken worlds and even forge planets out of debris p. 22

Invasion of the robotic telescopes p. 28

An asteroid crashes into an embryonic planet created from the debris of a titanic supernova explosion.

Inside light's dual personality p. 34

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Vol. 37 • Issue 7

Some Holes Just Need to be Filled!

The new 10mm Ethos has landed at your Tele Vue dealer! It slots right between the 8 and 13mm models making it ideal for all types of scopes, especially 8" SCTs, and it's everything you love about the Ethos series.

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— Vic Menard, *Astronomy Technology Today*

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— Stephen James O'Meara, *Astronomy*

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— Tom Trusock, *BBC At Night.*

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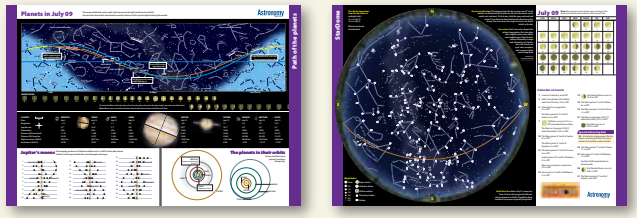

Path of the planets and StarDome.

Astronomy
How dying stars bring new planets to life
Invasion of the robotic telescopes
Inside light's dual personality

Cover: Lynette Cook for *Astronomy*

ON THE COVER

Scientists think planets can be born from the final gasps of aging stars. In this illustration, a second-generation planet forms from the dusty debris of a supernova explosion.

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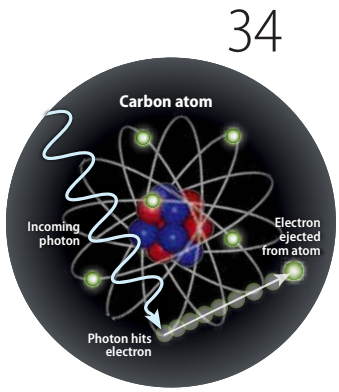

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Introducing some new departments

by David J. Eicher

Over the past couple of months, you may have noticed a new department or two in the magazine. This comes in response to comments we've received from readers about what you would like to see. In April, we introduced a department in the front of the magazine called "Astro Confidential," in which we've begun to feature a range of professional astronomers and what they are up to.

Copy Editor Karri Ferron has taken on "Astro Confidential" as the point person and has done a magnificent job on this project. Astronomy, as a subject, is so focused on galaxies, stars, planets, and comets that we sometimes lose the human element of what makes astronomy move forward. This month, on page 10, you'll read about Seth Shostak of the SETI Institute and how he interprets the meaning of detecting life on other worlds. You'll also get to know Neil deGrasse Tyson, director of the Hayden Planetarium in New York City, author, and television host. You'll learn how astronomy educator Michelle Thaller got interested in astronomy while she was growing up in — of all places — Waukesha, Wisconsin (the location of *Astronomy* magazine). You'll hear from Derek Fox of Penn State on gamma-ray bursts. And you'll read about the University of Hawaii's Lisa Kewley and her latest ideas about star formation.

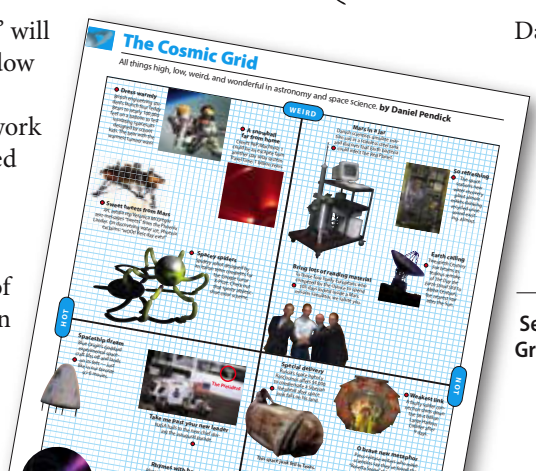
"Astro Confidential" will give you a unique window into the minds, backgrounds, and current work of astronomers scattered all across the globe. There's nothing else quite like it.

On the hobby side of things, we've also begun to give you a behind-the-scenes, exclusive glimpse at the personalities and plans behind the major telescope companies. In "Telescope Insider," Senior Editor Michael E. Bakich shares manufacturers' views of what's happening in the industry and what you'll see coming up in terms of new products. We also include a little exclusive philosophy about what makes these companies tick. This month features Joseph A. Lupica, president of Celestron. We've already featured Peter Moreo of Orion Telescopes and Binoculars, Brian Deis of Vixen Optical, and Russ Lederman of Denkmeier Optical. You'll find the Lupica interview on page 64.

Last but not least, this month we're introducing a new department craftily handled by the sharp, humorous mind of Associate Editor Daniel Pendick. Called "The Cosmic Grid," this feature plots some of the most unusual recent factoids, news bits, and random thoughts about astronomy, space exploration, and pop culture. Subtitled "All things high, low, weird, and wonderful in astronomy and space science," I think you'll appreciate this unique view of our times, and you'll find it on page 69.

Yours truly,

David J. Eicher
Editor



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Astronomy

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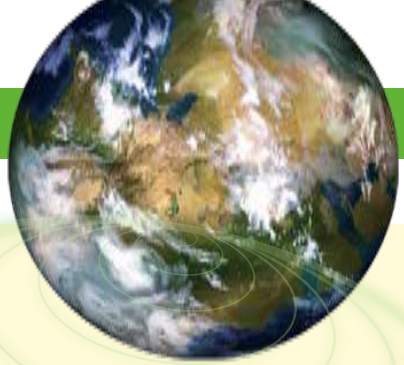
by Karri Ferron



OUR TURN

SETI Institute

Seth **Shostak**

Senior astronomer at the SETI Institute in Mountain View, California

What's the big deal if scientists find ET?

Polls say most Americans figure the government is hiding information about aliens, and nearly half think that gray guys from another world are sailing the skies without a flight plan.

It's an invasion, but no one seems overly concerned. So given this blasé attitude, do you think people would wig out if scientists discovered a signal from a star system hundreds of light-years away? Probably not. But a detected broadcast from deep in the cosmos would still be the biggest deal since the Roman Empire. I once surveyed two dozen journalists, and most said that finding ET was a weightier story than any they could recall.

A detection would speak to the public's enormous interest in aliens. For more than a century, extraterrestrial beings have populated novels, radio plays, films, and TV. Learning that these postulated beings have real counterparts somewhere above us would be as stunning as tripping across hard evidence of ghosts.

But there's more: Because any signal we snag from the skies will almost certainly be from intelligence more advanced than our own, it's possible we could be privy to information of great consequence.

Our ability to decode an alien signal is uncertain, but this much we can say: Two of the greatest questions in contemporary biology would be answered if we were to find ET. First is the matter of life. Does it spring up often, or is it a near-miracle? Second is the evolution of intelligence. Is high IQ an improbable accident of circumstance and history or a common feature likely to appear on many worlds? A signal would strongly indicate that neither our protoplasm nor our intellect is terribly special.

Still have doubts? Consider the 1996 NASA claim that it had discovered evidence of single-celled life from Mars in a meteorite. For 3 days this story topped the front page of *The New York Times* in a font big enough to read from low-flying aircraft. These putative Red Planet residents had been dead for nearly 4 billion years and required a better-than-average microscope to be seen. But it was heavy-duty news.

The discovery of ET would simply blow that away.

Astro**influences**

How did you get interested in astronomy?

Michelle **Thaller**

Manager of the Spitzer Space Telescope Education and Public Outreach Program

I became an astronomer partly because of the social approval. Whenever I showed interest in astronomy as a child, I was showered with attention. My dad, a geography professor at Carroll College in Waukesha, Wisconsin, was proud to have an offspring (a girl even!) who understood science. And by the 1970s, teachers knew it was important to encourage a girl to pursue science.

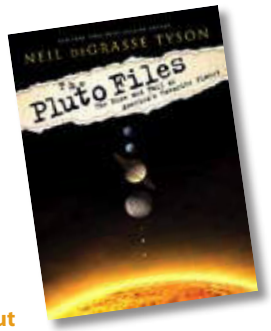
But of course, there had to be an innate interest. At an early age, I had an intense curiosity about how the physical world works. I realized if you keep asking "Why?" to just about anything, you get to physics — quantum mechanics, to be specific. I'm more of a physicist than anything.

Physics is basic to being comfortable with the reality in which we find ourselves. Can you imagine telling a child that those little white lights in the Wisconsin sky are actually vast, burning hydrogen bombs a million miles across and just too massive to explode? We're seeing them from trillions of miles away — can you imagine how hot they must be? Because I love all things dramatic — from dressing up in science-fiction costume to performing at Renaissance faires — these spectacular processes found in our universe grabbed my attention, and I was hooked for life.

Courtesy Michelle Thaller

To learn more about the people featured this month, visit www.Astronomy.com/toc.

Tell us about your "beef" with Pluto. I have no beef with Pluto. I only seek to celebrate the discoveries of the outer solar system. And one way to do that is to recognize Pluto as one of the largest members of this new swath of real estate that we call the Kuiper Belt. I think that's cause to celebrate rather than to be sad about Pluto's fate.

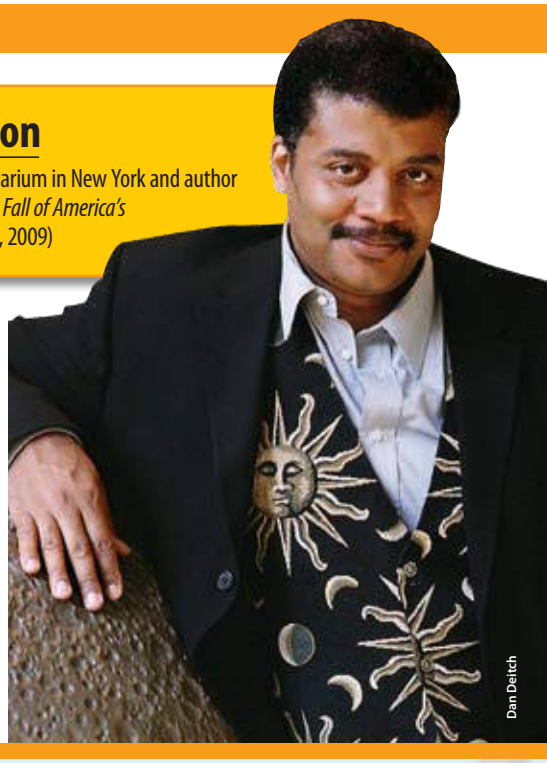


How did a kid growing up in New York City get excited about astronomy? It's all traceable to the planetarium, my access to the night sky. Initially, I thought it was a hoax because there were too many stars compared with the sky I saw from the Bronx. Only later did I realize that the Hayden Planetarium accurately captured the night sky when seen from dark sites. Today, when I look at the sky from a dark mountaintop, I find myself saying, "It reminds me of the Hayden Planetarium" — kind of embarrassing, but true. The night sky made its imprint on me at the planetarium, which makes me wonder: Would I have been less struck by the sky if I had grown up on a farm and seen it from my window every night?

What's been a "wow" moment in your career? Visiting the 100-inch Mount Wilson telescope in Southern California, which by today's standards is small and not visually impressive. But what made it practically spiritual was the knowledge that Edwin Hubble used this telescope to discover that the Milky Way is not alone in the universe among galaxies and that the universe itself is expanding. The birth of cosmology occurred at that place.

Neil deGrasse **Tyson**

Director of the Hayden Planetarium in New York and author of *The Pluto Files: The Rise and Fall of America's Favorite Planet* (W. W. Norton, 2009)


Dan Deitch

Astro**fascinations**

What fascinates you most about star formation?

Star formation is the beginning of an incredible series of events that can affect the path of an entire galaxy. When gas becomes dense enough, it collapses under its own gravity and forms stars. The hot young stars emit light with such high energies that the surrounding gas becomes excited by absorbing ultraviolet and X-ray light. Electrons soak up this energy and use it to escape their atoms and speed away, colliding with other atoms.

Surrounding dust particles also absorb the high energies from the hot young stars. As they absorb the light from these stars, the particles heat up and emit light at infrared wavelengths that we can see with large infrared telescopes.

Inside the stars are chemical production factories — with atoms such as oxygen, carbon, and nitrogen being created in vast quantities. As the stars evolve, huge stellar winds and supernovae drive these atoms out of the stars and into the surrounding gas, changing the chemical reservoir of a galaxy forever. If there is a large amount of star formation, the stellar winds and supernovae can join forces and form a gigantic wind that can cover the entire galaxy, driving gas and dust out of a galaxy and into the pristine emptiness of space.

I am in awe of the sheer size and gigantic amount of energy involved in these processes. There is a fantastic amount of physics that we know — and an equal amount that we don't know — about star formation.

Courtesy Lisa Kewley
M42: Jason Ware

Lisa **Kewley**

Hubble Fellow at the University of Hawaii's Institute for Astronomy

Astro**ideas**

Where is the study of gamma-ray bursts going?

Gamma-ray bursts (GRBs) — the universe's brightest explosions — are beginning to develop a fan base outside academic astronomy. Two years ago, the History Channel interviewed me for "Mega Disasters: Gamma-Ray Burst," a program about a hypothetical explosion within the Milky Way just 3,000 light-years from Earth.

The show cataloged the plagues that such a nearby burst would rain down on Earth: blinding light, electromagnetic pulses obliterating the ozone layer, and a planet-wide deluge of acid rain sufficient to trigger a mass extinction. At the end of the show, a clarification: The next such burst is probably a billion years in the future.

Those of us who study GRBs tend to focus on their less dramatic aspects. For example, they make great "cosmic lighthouses," illuminating gas and dust for billions of light-years along their lines of sight.

At the top of my list right now is the prospect of using GRBs from the "Cosmic Dark Ages" to reveal the nature of the sources — supermassive stars, galaxies, and black holes — that brought light back to the cosmos less than a billion years after the Big Bang.

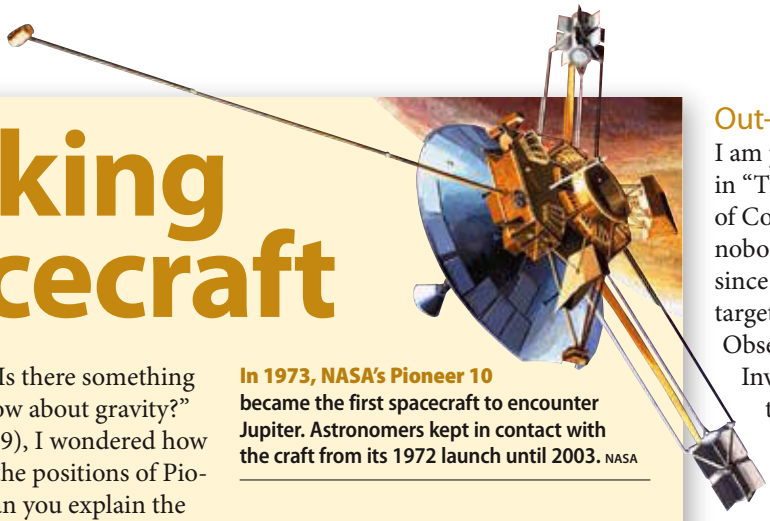
Efficiently exploiting GRBs for this purpose will require a new satellite, which our Penn State-led team is proposing to NASA. If we are selected, the next few years will involve a lot of meetings, project reviews, and challenges. And if we succeed, the years after that will be the most exciting yet, for us and for GRB fans everywhere.

Courtesy Derek Fox

Derek **Fox**

Assistant professor of astronomy and astrophysics at Penn State University

Stalking spacecraft



In 1973, NASA's Pioneer 10 became the first spacecraft to encounter Jupiter. Astronomers kept in contact with the craft from its 1972 launch until 2003. NASA

After reading "Is there something we don't know about gravity?" (March 2009), I wondered how scientists measure the positions of Pioneers 10 and 11. Can you explain the method? **— Jack Coate,** Ludlow Falls, Ohio

The Pioneer spacecraft, launched in 1972 and 1973, each carry a radio transponder for precise positional tracking. The tracking system used in conjunction with the propulsion system got the spacecraft to their encounters with Jupiter, where they recorded scientific measurements and obtained the first spacecraft images of Jupiter. Pioneer 11 continued on to a successful close approach with Saturn in 1979.

The transponder can receive a continuous radio transmission from Earth's surface at about 2.3 gigahertz. This is a frequency reserved today for commercial wireless use. In each Pioneer spacecraft, its transponder turns the radio waves around and sends them back to Earth at a slightly different frequency using 8 watts of power from an antenna attached to the craft. That is enough power that even far beyond Neptune large antennae and sensitive digital receivers of NASA's Deep Space Network (DSN) on Earth can record the received frequency and compare it with the frequency that was sent out. The difference in frequencies represents a Doppler shift caused by the relative motion of the spacecraft and the tracking station. The Doppler shift tells us the spacecraft's speed along the line of sight, which is the basic information used to determine the craft's trajectory and velocity. By using Einstein's modification of Newton's laws of motion, we can calculate an orbit with attributes that match the measured Doppler shift.

The DSN used the same principle when tracking more modern spacecraft during Earth flybys. The radio frequency now sits outside the commercial band, at about 8.3 gigahertz, but the DSN still records the Doppler shift, and the orbit determination is much the same as it was almost 40 years ago. **— John Anderson,** Consultant for Juno and Rosetta space missions

Gravity and cosmic expansion

Could the expansion of the universe cause some of the anomalies discussed in "Is there something we don't know about gravity?" (March 2009), or are the numbers too big? **— Dan Sweeney,** Cedar Rapids, Iowa

Some astronomers have suggested this. The rate at which the universe is expanding — called the "Hubble constant" — currently has a value of 71 kilometers per second per megaparsec (from multiple surveys). If you take that value and multiply it by the speed of light, you get an acceleration that is just about right to explain the Pioneer anomaly. That acceleration must be directed toward the Sun in order to slow the Pioneer spacecraft the amount observed.

However, the cosmic expansion affects the solar system a negligible amount. Plus, if it did affect our solar system, it would be directed away from the Sun. Even galaxies and clusters of galaxies are too tightly gravitationally bound to participate in the expansion. Astronomers know of no mechanism that could connect the four anomalies I mentioned in my article with the expansion of the universe. **— John Anderson,** Consultant for Juno and Rosetta space missions

Out-of-sight comet

I am puzzled by *Astronomy*'s references in "The Sky this Month" to the visibility of Comet 85P Boethin. The trouble is nobody seems to have seen this comet since 1986. In fact, it was an intended target for NASA's Extrasolar Planet Observation and Deep Impact Extended Investigation (EPOXI, which is a continuation of the Deep Impact mission). The project scientists planned to recover the comet for its 2008 apparition, but to no avail. It disappeared from view. Yet *Astronomy* declares it as an easy target for amateurs in its December, January, and February issues. **— John Sheff,** Cambridge, Massachusetts

Because of the editorial cycle here at Astronomy *magazine, we work quite far ahead. The authors wrote the February 2009 column for "The Sky this Month" in July 2008. At that time, astronomers expected the comet to be around 20th magnitude and then brighten to 10th magnitude in early 2009.*

By the time it should have been visible and there was an indication that it wasn't performing as expected, we were way beyond being able to report on it because those magazine issues had already gone to the printer. We apologize for the confusion. **— Richard Talcott,** Senior Editor

Corrections

In "Is there something we don't know about gravity?" (March 2009), the caption in the upper right of page 25 should say, "The perihelion of Mercury advances 574 arcseconds per century, more than Newton predicted."

In "The telescope's 400-year revolution" (May 2009), the photographs of Mount Wilson Observatory's 60-inch and 100-inch telescopes (on page 39) should be credited to Mount Wilson Observatory Superintendent Dave Jurasevich.

— *Astronomy* Editors

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Our editors have created videos to help you make the most of your time under the summer sky. *Astronomy* Editor David J. Eicher's video features deep-sky targets for larger scopes. Senior Editor Michael E. Bakich's video highlights some of his favorite summertime targets visible through a 4-inch or smaller telescope. Both of these videos are available to *Astronomy* magazine subscribers at Astronomy.com/videos.

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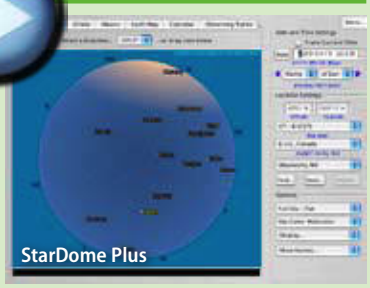

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Strange Universe

by Bob Berman

Facing reality

What's real becomes blurry when scientists question familiar concepts.

Real and *unreal* get thrown around a lot, in pop culture and also in science. Most of us first encountered these notions in high school math when forced to learn about imaginary numbers. In real life, there's no such thing as the square root of –1. But engineers use $\sqrt{-1}$ for actual applications like circuit design and fluid dynamics. Does that make it sort of real?

"What is 'real'? How do you define 'real'?" asked Morpheus in *The Matrix*. Good question. Even widely accepted assumptions in science and everyday life have yielded surprising twists after careful analysis.

Time, for example, now appears to be a mere ordering process created by the mind's circuitry. What we perceive as time is the specific sensible way our brains arrange complex electrical inputs. The widespread notion of a self-existing temporal grid is almost certainly illusory.

Space, too, *appears* real — a vast, edgeless container objects move around in. We even describe empty space as having properties such as curvature. Yet space is probably just a tool of animal perception.

How might space be unreal? Let us count the ways:

1. Many objects and their boundaries inherit meaning solely from language and custom.

2. Empty space is never really empty.

3. The gap between objects depends on the observer's speed and gravitational field. Distance mutates as if in a dream.

4. Certain particles, although far apart, instantly affect each other as if there's no separation between them.

5. All characterizations of space are actually descriptions of moving objects.

Despite all this, we'll continue acting as if space and time are real because, like imaginary numbers, they're useful. They help us make sense of the world.

Even outside the physical sciences, researchers are examining many long-held assumptions about reality. Take free will. Not at all controversial, you might think — but you'd be wrong. Albert Einstein often said he was sure it does not exist and found inspiration from German philosopher Arthur Schopenhauer's saying, "A man can do as he wills, but not will as he wills." In 2008, brain researchers reliably predicted which hand subjects would raise as much as 10 seconds before they were even aware they'd made a decision! Brains apparently work automatically, like kidneys, and decisions just happen. How would "control freaks" handle this?

Modern astrophysics is a fascinating battlefield between maybes and what-ifs.

Then you have pseudo-science, those various dream-level realms of society, each its own bizarro world. Astrologers wouldn't know reality if someone hit them over the head with a Klein bottle. To them, a tiny chunk of ice called Pluto influences your love life. And your stubborn personality comes from the distant stars of Taurus the Bull. Hello?

The make-believe realms are too numerous to list. Alternate Reality #714 contains 50 million Americans who think a long-gone civilization or a person like Nostradamus somehow knew the future. How do these wacky notions get started? Major culprits include the many phony "translations" of Nostradamus, where lines from his quatrains are altered and switched around to create seeming predictions of things like, say, doomsday.

If you show them an actual scholarly Nostradamus translation like that of Liberté E. LeVert, revealing the true endless drivel ("Burned by thunders, at 23 the sixes, the foolish woman shall fall from high places"), they're not interested. Who needs reality? These people *want* to believe the world will end in 2012.

Back to actual science, which sometimes contains intriguing items that *definitely* don't exist. Milkomeda isn't real, at least not today. But it could be born after all earthly life is toast in 5 billion years. It's a huge galaxy that will probably form after our Milky Way collides with Andromeda.

Astrophysicists routinely confront various "What's real?" issues. A black hole must collapse into a singularity if it strictly obeys general relativity. That's where a massive star gets smaller and smaller, like Alice, until it occupies no space at all and its density zooms to infinity. You'll often find this "infinitely dense, zero volume" description in textbooks. But is it real or imaginary? What could it mean to exist but take up no space? What could "infinite density" actually connote? Are these just Casper-like ghost labels? Might not some unknown factor like particle physics' strong force spring up under such extreme conditions to prevent the impossible?

Singularities are just the iceberg's tip. Modern astrophysics is a fascinating battlefield between maybes and what-ifs. Higgs Bosons, neutralinos, events before the Big Bang, space-time, dark energy, branes, Schrödinger's cat paradoxes, parallel universes, string dimensions … how many will prove real someday? And which will forever exist only in the feverish minds of theorists?

That's why we're in this theater — to catch the next act of this amazing show. Could we even choose to leave? Get real!

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$$(1 - p) \times 5 = p \times 2$$

$$5 = p \times 7$$

$$p = \frac{5}{7} = 0.714$$

which the expected value is infinity; something has to be wrong, but can you guess what it is?

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Professor Michael Starbird is a distinguished and highly popular teacher with an uncommon talent for making the wonders of mathematics clear. He is Professor of Mathematics and a Distinguished Teaching Professor at The University of Texas at Austin, where he has received the President's Associates Teaching Award, the Jean Holloway Award for Teaching Excellence, and the Friar Society Centennial Teaching Fellowship.

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Secret Sky

by Stephen James O'Meara

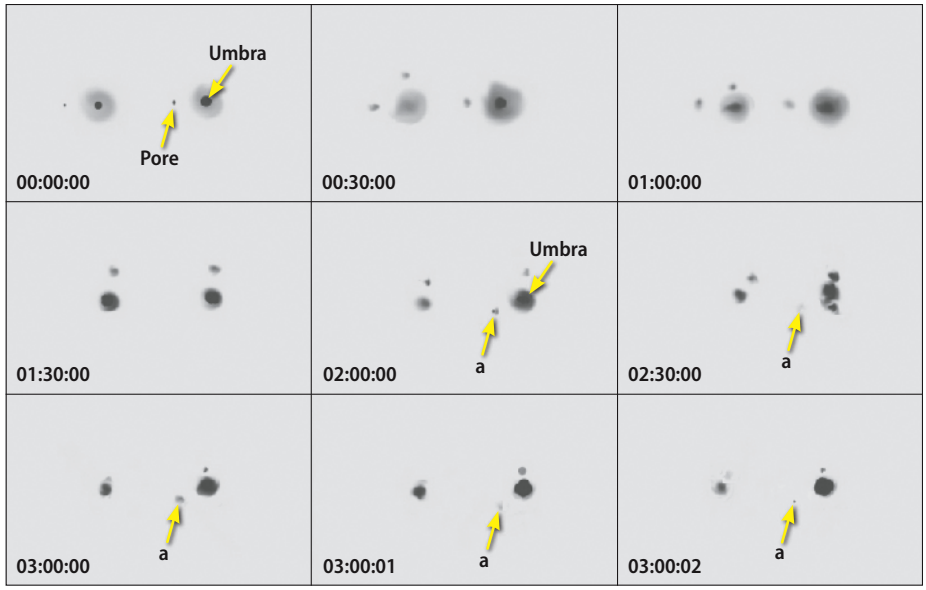
Magic times on the Sun

The new solar cycle just began, which makes the Sun an exciting observing target.

In astronomy, we're accustomed to waiting days, weeks, or even months to see tiny changes in the appearance or position of heavenly bodies. But if you want to see some real-time action, grab hold of a telescope with a safe solar filter and keep vigil on the Sun for new and emerging sunspots. You just might catch some mysterious white-light phenomena that come and go before your own eyes.

These are exciting times for solar observers because we're near the beginning of an 11-year solar cycle (Cycle 24). The excitement began January 4, 2008, when a sunspot with magnetic polarity opposite that of sunspots of the previous cycle appeared 30° north of the Sun's equator.

All solar cycles begin in the same way — with magnetically reversed sunspots appearing at high solar latitudes. As the years pass, new spots form progressively closer to the equator. As a solar cycle draws to an end, old-cycle spots hug the Sun's equatorial regions before fading away while the new cycle takes over.



To ensure your eyes aren't tricking you, sketch what you see. The author sketched these changing sunspots October 11, 2008. Note how pore *a* changes through time. Stephen James O'Meara

An eye for change

A new solar cycle does not jump immediately into high gear; it takes time for one to establish itself. Until it does, it's possible to see new-cycle and old-cycle spots on the Sun's surface at the same time for about a year. During this transition period, you may see some fast and curious changes happening to the new-cycle sunspots as they struggle to survive.

Solar physicist David Hathaway of NASA's Marshall Space Flight Center in Huntsville, Alabama, notes that as of September 2008, sunspot counts were at a 50-year low. So while sunspot activity has been extremely lean since the start of Cycle 24, the little activity that has occurred has been visually fascinating. You just have to have an eye for detail … and the mysterious.

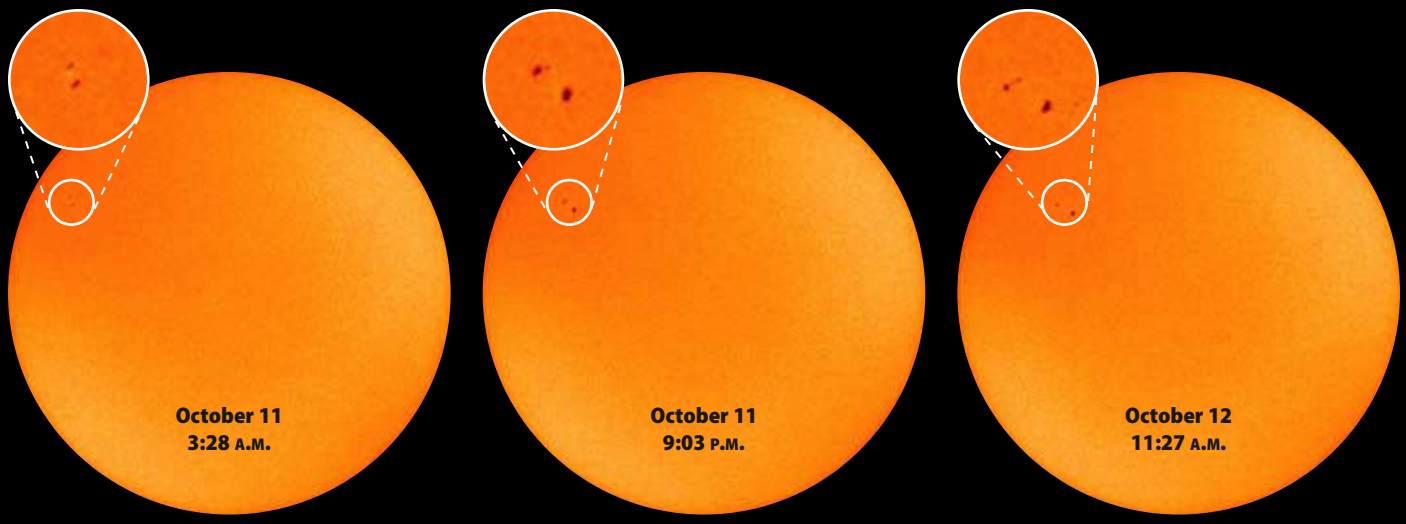
Before you begin your quest, it's valuable to have a source of information that can tell you whether a new sunspot has recently formed or is forming. The web site SpaceWeather.com is a good place to start. It provides news and information about the Sun-Earth environment and more. It posts a daily image of the white-light Sun from the Solar and Heliospheric Observatory (SOHO) and tells you if any sunspots are visible and where to look.

REMEMBER: Never look directly at the Sun with your eyes or through binoculars or a telescope without safe solar filters.

Pore seeing

One event you'll want to catch is the emergence of a new-cycle spot, especially when it's just a "pore." This small but dark protospot (one with no outer shadow-like penumbra) can turn into a sunspot. The action is in the transformation. The Sun's surface has a mottled appearance called granulation. Pores usually appear where several granules touch. If you catch sight of one, keep an eye on it and take good notes.

Pores can swell to prominence within a matter of minutes or even seconds. They can also fade from view just as fast — so fast that you'll undoubtedly question your eyesight. That's why noting any changes is important. Start by recording the pore's size and how dark it is. Both



The October 11, 2008, sunspot changed rapidly in these observations from the Solar and Heliospheric Observatory (SOHO). Notice the movement and changing size of the sunspots over the course of 32 hours. These sunspots belong to the new solar cycle. Compare these SOHO images to what the author sketched in the image at left. SOHO/MDI (ESA & NASA)

can fluctuate rapidly, sometimes flickering in a matter of seconds.

Be sure, however, to also monitor the surrounding granulation to confirm whether the action is not an artifact of atmospheric instability. That said, the best times to make these observations are under steady seeing.

A stalwart pore may become a true sunspot by forming a penumbra. Other pores may appear near the new spot. These attendant pores can also come and go on a whim. They might even shuffle their positions. It's not a celestial charade, but something akin to a sleight-of-hand trick — one performed so quickly and deftly that onlookers cannot observe the manner of execution.

Documenting the action

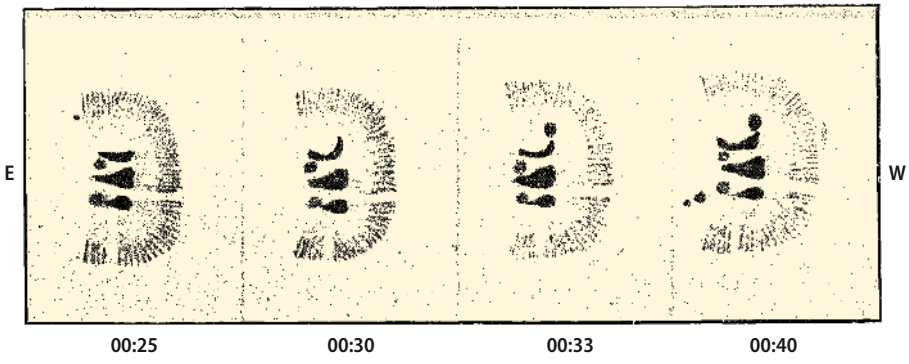
On October 11, 2008, SpaceWeather.com announced that a new Solar Cycle 24 sunspot pair was emerging near the Sun's northeastern limb — the biggest and most active region on the Sun in months. Curious, I placed solar filters over the objectives of some Orion 25x100 binoculars and found the small sunspot pair. Both spots had a central umbra and shadowy penumbra; a pore accompanied the leading spot.

As the minutes passed, the drama that unfolded was nothing short of remarkable. Before my eyes, the intensity of the following spot's penumbra waxed and waned as two pores started to form near it. Minutes later, the intensity of both spots and their associated pores diminished significantly. Then, as if by magic, both spots lost their penumbras in the blink of an eye, as the pores simultaneously vanished.

Suddenly, a new pore formed above the umbra of the leading spot, and another began violently pulsing in and out of view in just seconds! The pulsing bursts looked like puffs of smoke chugging out of a volcanic vent.

At one point, a bead of intense white light replaced the dark pore before it disappeared. Shortly thereafter, the umbral portion of the leading spot split into three distinct fragments, so the umbra then appeared more elliptical than circular. This change was also short-lived, as the structures continued their battle for life.

The drama was so intense that I had to wonder if an unstable atmosphere was fooling my eyes. So I placed a safe solar filter over the objective of my 5-inch f/5 Tele Vue refractor, turned the scope to the spots, and viewed the same types of action at high power.



Within minutes these sunspots changed before William F. Denning's eyes. Denning made this observation January 22, 1904, through a 4-inch refractor. *The Observatory*

Nothing new

Seeing such rapid changes on the Sun is not a novelty, but it does require patience, diligence, and some luck. The action also is not limited to the start of a solar cycle.

For instance, on January 22, 1904, the noted British observer William F. Denning saw a large sunspot "in a state of agitation," witnessing in the matter of minutes "some remarkable changes," including the sudden appearance and disappearance of some little spots.

"During occasional solar observation since 1865," Denning noted in the April 1904 issue of *The Observatory*, "I have never previously remarked such rapid alterations in detail. Some of these were perceptible in a very few seconds and could be distinctly traced in their operation. Unsteady definition had nothing to do with the phenomena observed."

So keep vigil on the Sun, and see if it doesn't conjure up something of interest. Send your reports to me at someara@interpac.net.

Bad memories Controllers rebooted the Mars Odyssey orbiter's computer system to wipe out memory glitches accumulated since its last restart 5 years ago.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

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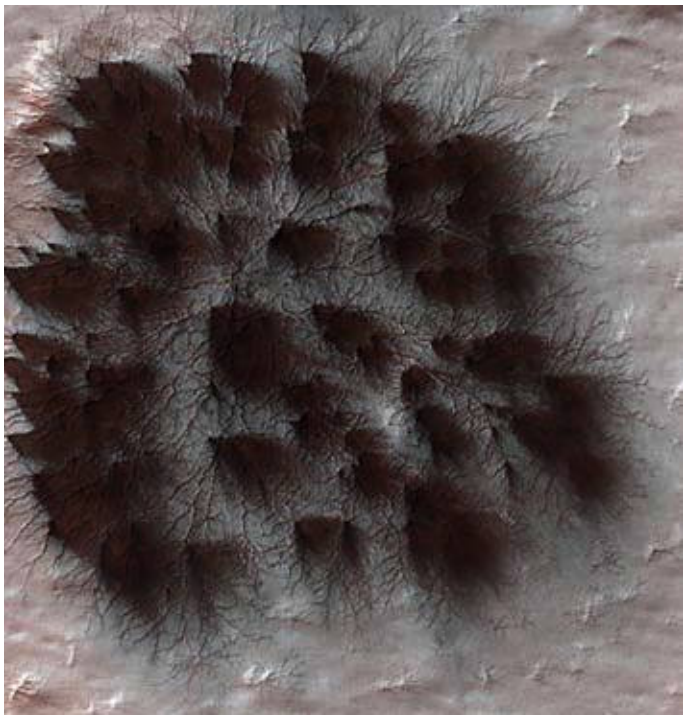


Spring is sprung. Carbon dioxide gas plumes break through temporary ice caps to indicate the beginning of spring on Mars. NASA/JPL/University of Arizona

Astronomers image springtime on Mars

The University of Arizona's High Resolution Imaging Science Experiment (HiRISE) aboard NASA's Mars Reconnaissance Orbiter snapped a photo of carbon dioxide plumes escaping seasonal polar caps February 4. The gas plumes mark the start of spring on the Red Planet. On March 25, the HiRISE team released this image and many others of Mars' south polar region.

Mars, like Earth, has permanent ice caps. Unlike on Earth, however, carbon dioxide in the martian atmosphere changes directly to frost during the winter, forming seasonal polar caps. In springtime, returning sunlight heats the soil beneath the layer of carbon dioxide — also known as dry ice. When the temperature warms, carbon dioxide changes directly from frost to gas.

The temporary ice cap thins from both the top and bottom. "Where gas under the ice finds a weak spot or a crack, it will flow out of the opening, often carrying a little dust from the surface below," says Candice J. Hansen-Koharcheck, HiRISE deputy principal investigator. The dust leaves behind starburst-shaped deposits. **— LIZ KRUESI**

20 Next planetary flagship mission targets Jupiter

21 Dark matter provides cushion for galaxies

21 Fermi's high-energy eye maps the sky

Did Phoenix spot liquid droplets on Mars?

Bloblike spots seen on one of the Phoenix Mars Lander's legs might be highly salty droplets of liquid water. During the mission, the blobs moved and changed size. If the blobs really were droplets, it would represent the first observation of liquid water on Mars.

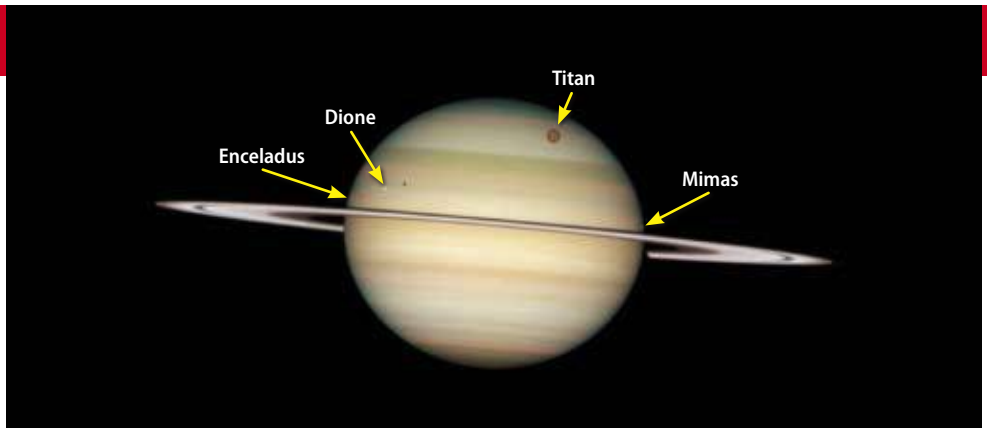
Researcher Nilton Renno of the University of Michigan in Ann Arbor presented the controversial hypothesis March 23 at the Lunar and Planetary Science Conference in The Woodlands, Texas. A detailed report by Renno and his colleagues was accepted for publication in the *Journal of Geophysical Research*.

Water exists on Mars as ice or water vapor. But owing to the planet's low surface pressure and temperature, water should not normally exist as a liquid.

Renno and his colleagues assert that the droplets splashed up from a pocket of briny water as Phoenix landed on rocket thrusters May 25, 2008. High salt content in the droplets may have lowered the freezing point of water to around –90° Fahrenheit (–68° Celsius). This would have allowed droplets to exist even at subzero temperatures that prevail in Mars' north polar region. **— DANIEL PENDICK**

NASA/JPL-Caltech/University of Arizona/ Max Planck Institute

Droplets on Mars? In a controversial claim, a team of scientists says this image shows liquid droplets of super-salty water on a strut supporting the Phoenix Lander.



Shall we dance? **Astronomers using NASA's Hubble Space Telescope caught four of Saturn's moons and their shadows parading in front of the planet February 24. Titan, the largest of Saturn's moons, is larger than our innermost planet Mercury.** NASA/ESA/The Hubble Heritage Team (STScI/AURA)

Four moons dance across Saturn's face

On March 17, astronomers released Hubble Space Telescope images of four of Saturn's moons transiting Saturn's face at the same time. Such transits are visible from Earth only when we view Saturn's rings nearly edge-on. Hubble snapped these photos February 24.

Like Earth, Saturn is tilted relative to its orbit around the Sun. Twice during Saturn's year (which equals about 29.5 Earth years) we see the planet edge-on. The last time we witnessed a ring-plane crossing was 1996. During September, Saturn's rings will be edge-on to us again, but the planet will be too close to the Sun for us to observe it. Therefore, now is a great time to view transiting moons across Saturn's face.

In the released Hubble images, four moons and their shadows traverse Saturn's face in several hours. At the time of these transits, Saturn was about 775 million miles (1.25 billion kilometers) from Earth. **— L. K.**

New evidence pushes back oxygen date for Earth

New evidence suggests organisms may have begun manufacturing oxygen much earlier in Earth's history than scientists thought. Researchers led by geochemist Hiroshi Ohmoto of Pennsylvania State University in University Park reported their findings in the April issue of *Nature Geoscience*.

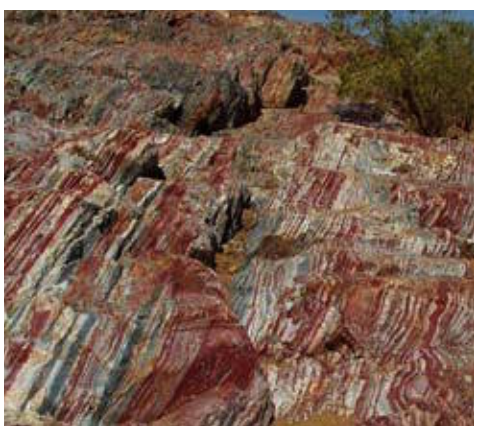
Scientists have found chemical compounds called iron oxides all over the world dating back to about 2.2 billion years ago. The oxides form when iron reacts with oxygen.

The oxides are evidence that bacteria were releasing oxygen into the environment at least 2.2 billion years ago. Other evidence has turned up for oxygen-making as far back as 2.7 billion years ago, although this remains controversial.

The new evidence discovered by Ohmoto's group could extend the record even further back. The researchers found hematite, a type of iron oxide, in 3.46-billion-year-old rock in the Marble Bar chert formation in northwestern Australia.

Analysis of hematite-bearing rock in the chert formation suggests the oxides formed deep underwater when iron-rich water gushing from volcanically heated seafloor vents mixed with cooler oxygen-rich seawater. Crystals of hematite formed and then were incorporated into sedimentary rock.

If the team's analysis is correct, it could mean Earth possessed an oxygen-rich atmosphere when the hematite formed. And that would mean photosynthesis — fundamental to life on Earth — originated 760 million years earlier than previous evidence suggested. **— D. P.**


Hiroshi Ohmoto

Rusty record. **The reddish tinge of this ancient rock formation in Australia betrays the presence of iron oxides — and evidence for a much earlier origin of the first oxygen-producing organisms.**

QUICK TAKES

CLOSE SHAVE
Asteroid 2009 FH flew within 49,000 miles of Earth March 17, only twice the altitude of some satellites. The space rock measures about 65 feet across.

CASSINI'S PLAN B
The Cassini Saturn orbiter switched to backup propulsion thrusters March 12 after performance of its main system appeared degraded.

40 YEARS OF ESO
The European Southern Observatory's La Silla Observatory in Chile celebrated its 40th anniversary March 25.

QUIET SUN
As of March 31, the Sun remained free of blemishes on 78 out of 90 days, continuing an expected lull in the 11-year sunspot cycle.

ICY BLAST
A 2008 meteorite impact exposed bright-white subsurface ice on the Red Planet, Mars Reconnaissance Orbiter scientists announced March 27.

DOUBLE SPACE
On March 28, U.S. software merchant Charles Simonyi became the first two-time space tourist as he arrived on the International Space Station for a 10-day visit.

2,308 DAYS TO GO
On March 19, NASA's New Horizons probe passed one-third of the number of days (1,155 days) in its journey to Pluto. The spacecraft will arrive July 14, 2015, 3,463 days after launch.

SPLAT!
The Chinese lunar probe Chang'e-1 concluded its mission March 1 with a planned impact on the Moon. The orbiter blasted off October 24, 2007.

MOON RED RISING
New images released March 9 suggest that Mars' airless moon Deimos gets darker and redder with continued exposure to the space environment.

BARACK TO THE MOON
President Barack Obama's proposed budget, released February 26, continues support for a U.S. return to the Moon by 2020. The president's request for NASA totals $18.7 billion.

25 years ago in *Astronomy*

July 1984

The July 1984 issue of *Astronomy* featured an article about white dwarfs, the remnants of Sun-like stars. In "White dwarfs: Big things in small packages," physicist Anthony J. Nicastro wrote about how Sun-like stars form and evolve into white dwarfs.

Nicastro explained how white dwarfs are dense objects — they have the mass of our Sun crammed into a body the size of Earth. Extraordinary physics must occur within these stars to allow for such extreme densities.

While some white dwarfs eventually fade out of existence, those in binary systems can take a different route in their evolution, Nicastro explained.

10 years ago in *Astronomy*

July 1999

In the July 1999 issue of *Astronomy*, then Senior Editor Rex Graham wrote about the just-beginning Pluto debate in "Is Pluto a planet?" The discussion began some 10 years ago when a few astronomers proposed a dual designation for Pluto as a planet and a "minor planet." However, as Graham explained, the International Astronomical Union (IAU) argued that "Pluto was in no imminent danger of a dual-classification demotion." Ironically, the IAU downgraded Pluto to a "dwarf planet" 7 years later in 2006.

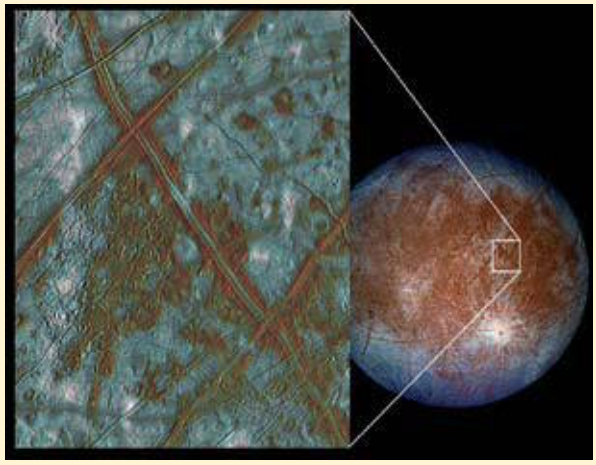
The debate stemmed from the big question of what defines a planet. From that definition comes the argument that if Pluto were discovered today, astronomers would classify it as a minor planet.

Even though the IAU recently declared Pluto a dwarf planet, the emotional debate rages on throughout the astronomical community and the general public. — **L. K.**

Next planetary flagship mission targets Jupiter

The Viking landers brought Mars to your living room in 1976. Several years later, the Voyager probes started a decade-long grand tour of the outer planets that launched a fleet of scientific careers. NASA's Cassini orbiter and the European Huygens lander have revealed numerous hydrocarbon lakes on Saturn's moon Titan.

The next grand planetary expedition, slated for launch in 2020, will be a joint NASA-European Space Agency (ESA) "system mission" to Jupiter and its largest moons. The space agencies will launch their spacecraft separately. The total cost will likely be near $4 billion.



Mixing it up. If Europa's icy crust is relatively thin, movement along the moon's innumerable icy fractures could allow deep ocean water — and whatever may live in it — to reach the surface, where space probes might spot it. NASA/JPL/University of Arizona

As for Saturn, we'll go there, too — perhaps with a robotic blimp and floating lake probe to explore Titan's surface in more detail — but not until after the Jupiter system mission. NASA and ESA officials announced the "Jupiter first, then Saturn" plan February 18 after a painstaking review of the pros and cons of both missions.

NASA's contribution to the scientific assault on Jupiter will be an orbiter to study Europa. Many scientists are convinced the moon's fractured ice crust conceals a liquid ocean. Planetary scientists consider Europa a candidate to host some form of life — perhaps colonies of microorganisms living near hydrothermal vents.

ESA's orbiter will target another of Jupiter's four large moons, Ganymede. This world sports a magnetic field and possibly a global ocean and molten core.

Before parking into their final orbits at Europa and Ganymede, the spacecraft will engage in a looping ballet of maneuvers to study Jupiter and its two other large moons, Callisto and Io. They will probe Jupiter's atmosphere, magnetic field, and rings.

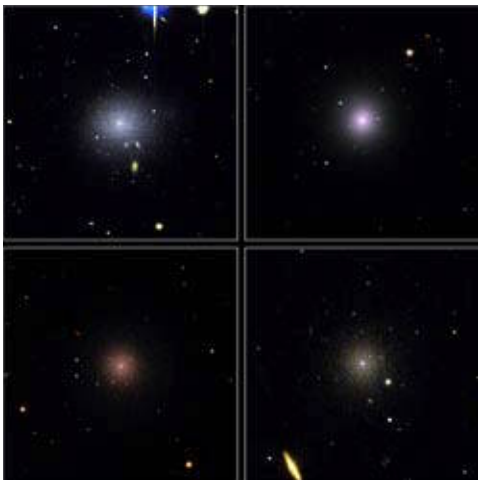
One controversial issue the Europa orbiter's instruments may not be able to resolve completely is the thickness of Europa's ice crust. If it's relatively thin — say, up to about 6 miles (10 kilometers) or so — there's a greater chance of mixing between the ocean and surface. In that case, the churning of Europa's crust could deposit traces of alien life at the surface. And that means scientists would not have to melt or drill through miles of ice to find evidence for life.

Alternatively, some scientists believe Europa's crust is at least 12 miles (20 km) thick. That would prevent direct mixing between the ocean and surface, which would limit the ocean's habitability to life and make it harder to reach its depths with a probe. Instead, scientists could look along one of the moon's numerous fault zones.

Instruments on the Europa probe will study the crust's internal structure and measure tidal movements. The craft will also study the moon's surface chemistry and further explore its chaotic terrain. The new data will hopefully improve understanding of the processes acting on Europa and its habitability for life.

But it's going to be at least 17 years until the probes lock into orbit around Europa and Ganymede. Jupiter junkies will get a quick fix if NASA's solar-powered Juno probe reaches the planet in 2016 as planned. The modest mission will target Jupiter's chemical composition and gravitational and magnetic fields. Until then, maybe it's time to dust off those Voyager flyby videos. — **D. P.**

2nd place star With its final set of solar wings, the International Space Station's maximum brightness exceeds that of Venus. Only the Moon and occasional flashes from Iridium Corp. communications satellites are brighter.



NASA/ESA/C. Conselice (University of Nottingham, U.K.)

Security blanket. These four dwarf galaxies are among 25 that astronomers scrutinized for the protective effect of invisible dark matter.

Dark matter provides cushion for galaxies

Astronomers using the Hubble Space Telescope have found new evidence that galaxies are embedded in clouds of invisible "dark matter." The team, led by Christopher Conselice of the University of Nottingham in England, published the finding in the March 1 *Monthly Notices of the Royal Astronomical Society*.

Hubble recorded many intact dwarf galaxies in the heart of the Perseus galaxy cluster. Because of the dense concentration, galaxies in clusters are usually ripped apart. But these dwarf galaxies are undisturbed, which makes astronomers think dark matter could be cushioning them from the gravitational pull of the other cluster members.

The astronomers found 29 undisturbed dwarf galaxies near the Perseus cluster's center. These galaxies showed no signs of star formation, which can be a result of tidal processes between galaxies. The astronomers then analyzed 25 galaxies' physical sizes and the distances between each galaxy and the cluster center. Because four galaxies were visually located near a bright star or galaxy, the astronomers couldn't accurately determine their radii and therefore omitted them from the study.

The astronomers found that 12 of those 25 require a large amount of dark matter to protect them from being ripped apart by the larger cluster members. They also found that fainter dwarf galaxies require a larger fraction of dark matter than more luminous dwarf galaxies. They, however, "cannot say whether the dark matter content of the dwarfs is higher than in the Milky Way Galaxy," says Conselice. About 90 percent of the Milky Way's mass is dark matter. — **L. K.**

BRIEFCASE

Characterizing twin Earths won't be easy

The James Webb Space Telescope (JWST) will be able to detect the possible life signs ozone and methane, but only for Earth-sized planets within about 20 light-years, astronomers say. Scientists from Harvard and JPL studied the JWST's ability to examine an earthlike planet's atmosphere as the planet passes in front of its parent star. The planet's atmosphere would filter the star's light. The study will appear in an upcoming issue of *The Astrophysical Journal*. — **L. K.**

Fermi's high-energy eye maps the sky

NASA's Fermi Gamma-ray Space Telescope has combined 3 months of data to create the highest-resolution map of the gamma-ray sky. From the map, scientists identified and described the 205 brightest sources in a paper submitted to *The Astrophysical Journal Supplement*. This paper is the mission's first science product. — **L. K.**

Ice volcanoes on Titan?

An area of Saturn's moon Titan appears to fluctuate in brightness, possibly from ice flows. This provides more evidence that Titan harbors ice volcanoes. A 3-D view of Hotei Arcus presented at the Lunar and Planetary Science Conference March 24 shows structures on the surface that tower 650 feet (200 meters) above their surroundings. Astronomers say slushy water and ammonia could have spurted up to Titan's surface during a "cryovolcanic" eruption and frozen, forming these structures. — **L. K.**

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A doomed star can awaken frozen worlds and even forge new planets out of death's debris.

by Ray Villard

How dying stars bring

"So I travelled, stopping ever and again, in great strides of a thousand years or more, drawn on by the mystery of the earth's fate, watching with a strange fascination the sun grow larger and duller in the westward sky, and the life of the old earth ebb away. At last, more than thirty million years hence, the huge red-hot dome of the sun had come to obscure nearly a tenth part of the darkling heavens."

When H. G. Wells penned the 1895 science fiction classic *The Time Machine*, he had his time traveler venture far into the future to witness Earth's final days. Wells accurately described the aging Sun swelling into a red giant, even if the timing was off. Nineteenth-century astronomers had no clue about nuclear fusion and thought the Sun could burn for no more than a few tens of millions of years.

Today's astronomers don't need a time machine to explore the solar system's fate. Observations of planets around other stars, combined with theory and simulations of how planets grow in circumstellar disks, are providing valuable insights.

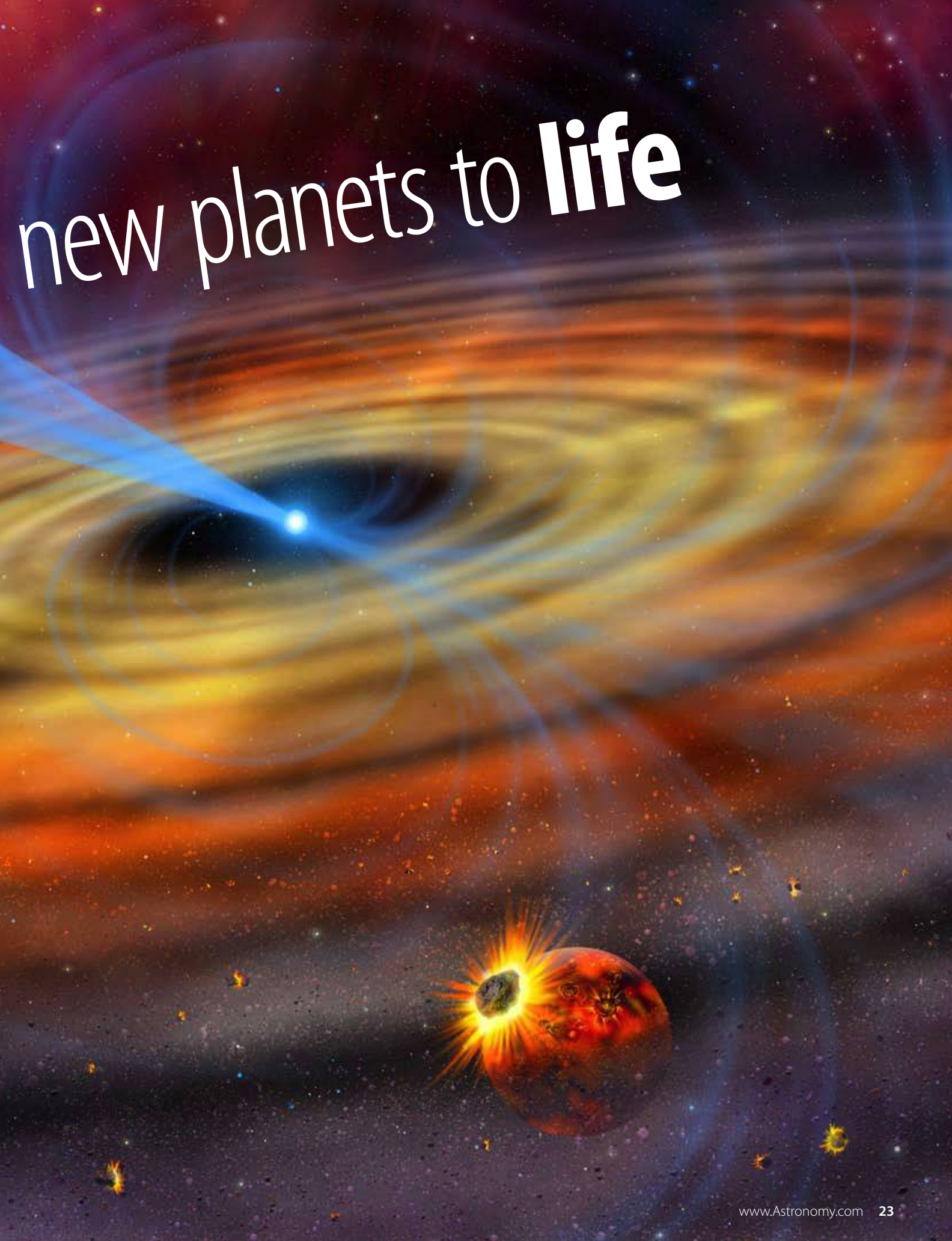
As their parent stars inevitably age and burn out, every inhabited planet across our galaxy faces the ultimate apocalypse — the destruction of its system and the likelihood of being reduced to a cinder.

Yet the emerging view of what happens to planets at the end of a star's life has more complexity than scientists once thought. What's more, the ever-shifting fortunes of survivability in the universe suggest one planet's apocalypse may be another's genesis.

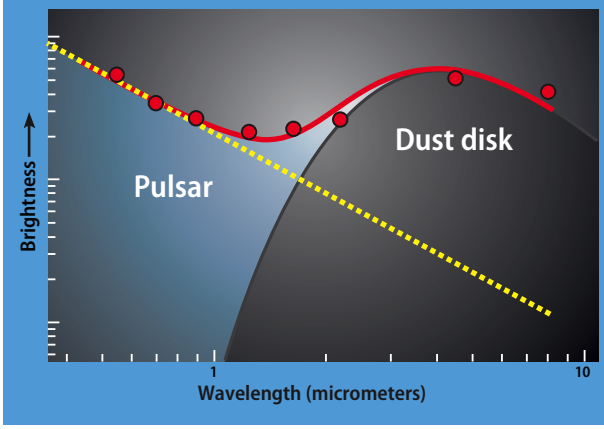
The outer limits for red giants

Roughly 5 billion years from now, the Sun will go through a late-life crisis. Fusion reactions will migrate to a hydrogen-rich shell

A planet starts to coalesce in the dusty disk surrounding a pulsar. This second-generation planet forms from the debris of a supernova explosion, which also created the rapidly spinning pulsar. Lynette Cook for *Astronomy*



new planets to **life**



A dusty pulsar

A dust-rich fallback disk surrounds the pulsar 4U 0142+61. NASA's Spitzer Space Telescope detected the disk by measuring the system's excess brightness at infrared wavelengths. The red dots represent the observations; the dotted yellow line shows what the system's brightness would be if no dust existed. *Astronomy:* Roen Kelly

surrounding an inert core of helium. The Sun's internal temperature will spike, and our star will expand into a red giant. Like a runaway hot air balloon, the Sun's outer layers will reach escape velocity and peel off into space. As the Sun begins losing mass, the planets' orbits will widen to conserve the solar system's angular momentum. Earth will migrate out to Mars' current orbit, and the Red Planet will move proportionally farther out.

That sounds like good news for Earth, except that tidal forces between the expanding Sun and Earth will drag our planet back inward. This gloomy forecast comes from a recent study by astronomers Robert Smith of England's University of Sussex and Klaus-Peter Schröder of Mexico's University of Guanojuato, who calculated how much mass the Sun will lose.

Earth will produce a tidal bulge in the bloated Sun, whose spin rate will slow to a crawl. This bulge will lag slightly behind Earth's orbital position, like a stubborn dog on a leash. The gravitational tug from the bulge will slow Earth's orbital velocity and cause our planet to spiral in toward the Sun. Friction from the tenuous gases in the Sun's ballooning atmosphere will speed up this death spiral.

A study by Mario Livio of the Space Telescope Science Institute in Baltimore and his then postdoctoral student, Lionel Siess, predicts that any gas giant planet within 300 million miles (480 million kilometers) of a red giant star also will fall into its star. But such planets will leave forensic clues to their demise. The giant star may eject a shell of dust, spin faster from absorbing the planet's angular momentum, and have an excess of the rare element lithium from the planet's vaporization. Astronomers observe these characteristics in 4 to 8 percent of the red giant stars in our neighborhood.

A Sun-like star's evolution into a red giant certainly would render the inner region of its planetary system uninhabitable. Yet all hope may not be lost. The habitable zone will expand along with the star. This will warm once-frozen planets and their moons, bringing a brief springtime after a 10-billion-year winter.

Under the warm glare of the awakening giant star, a frozen moon's icy top layer will melt quickly into liquid water. Ancient craters will dissolve into the warming seas. After being in hibernation for all of its star's main sequence lifetime, the moon's newborn oceans, laden with a carbon-rich broth, could spring to life.

Astrophysicists Bruno Lopez of France's Nice Observatory, Jean Schneider of Paris Observatory, and William Danchi of NASA's Goddard Space Flight Center estimate that as the Sun balloons to a red giant, the habitable zone will sweep through a range of 185 million to 840 million miles (300 million to 1.35 billion km) radius. Conditions in this region could remain habitable for as long as 1 billion years.

According to some theories, life on Earth may have begun as soon as a few hundred million years after Earth cooled down from its fiery birth. If life elsewhere could form within a billion years of when conditions become ripe, then newly inhabited planets could exist around many red giant stars.

Near the end of a star's first epoch as a red giant, its core grows hot enough that the leftover helium "ash" amassed during the star's lifetime ignites. At a temperature of 100 million degrees, the born-again core furiously fuses helium into carbon and some oxygen. For up to a billion years or so, the star steadily burns helium. Life could then have a chance to develop in an extended habitable zone stretching from 650 million miles to 2 billion miles (1.05 to 3.3 billion km).

Assuming gas giant planets dwell at these distances from Sun-like stars, as they do in our solar system, the possibility of life would expand to many new worlds. Once frozen, carbon-rich moons like Saturn's Titan would thaw out and become incubators for the first stages of life.

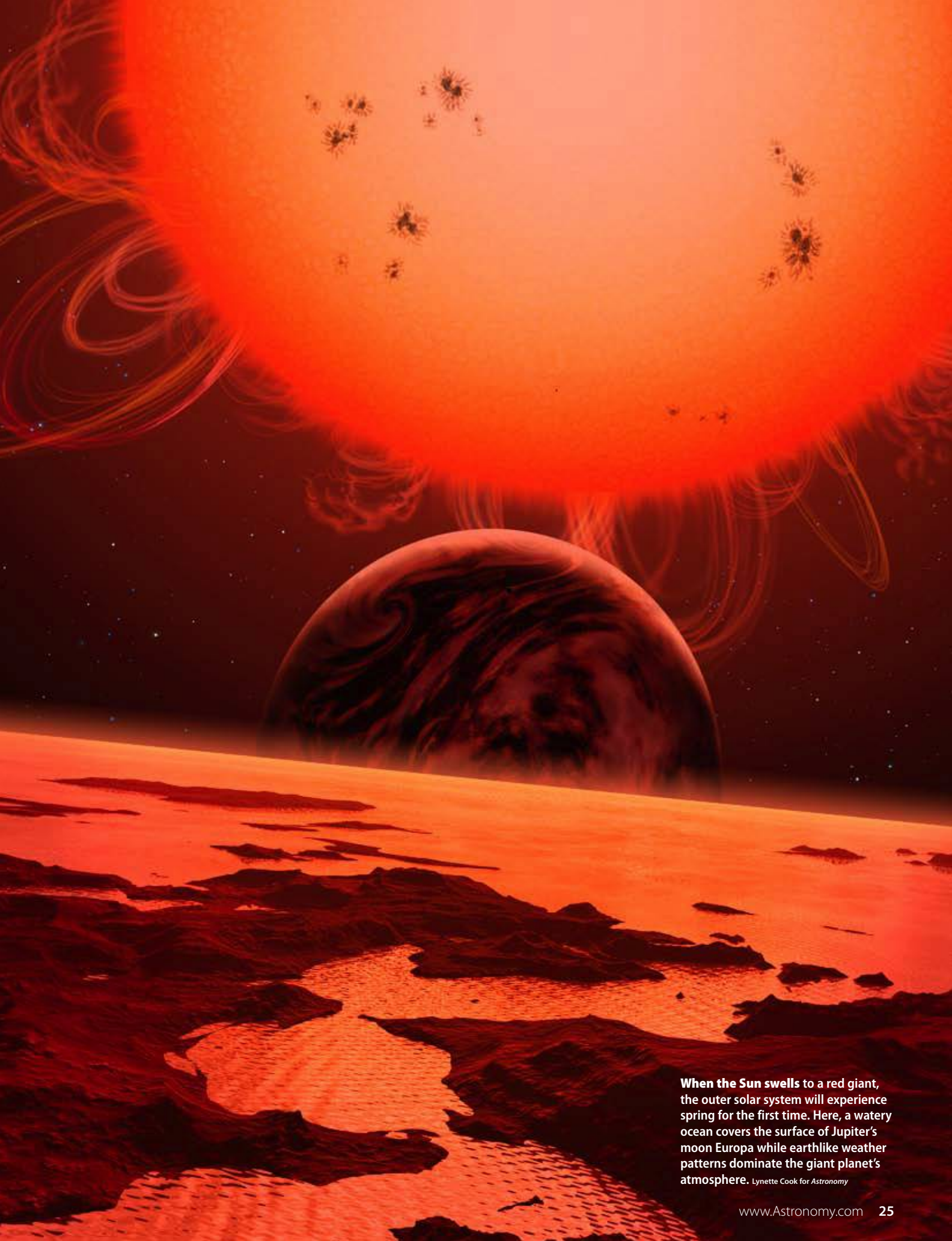
A Sun-like star's evolution into a red giant certainly would render the inner region of its planetary system uninhabitable.

New planets for old stars

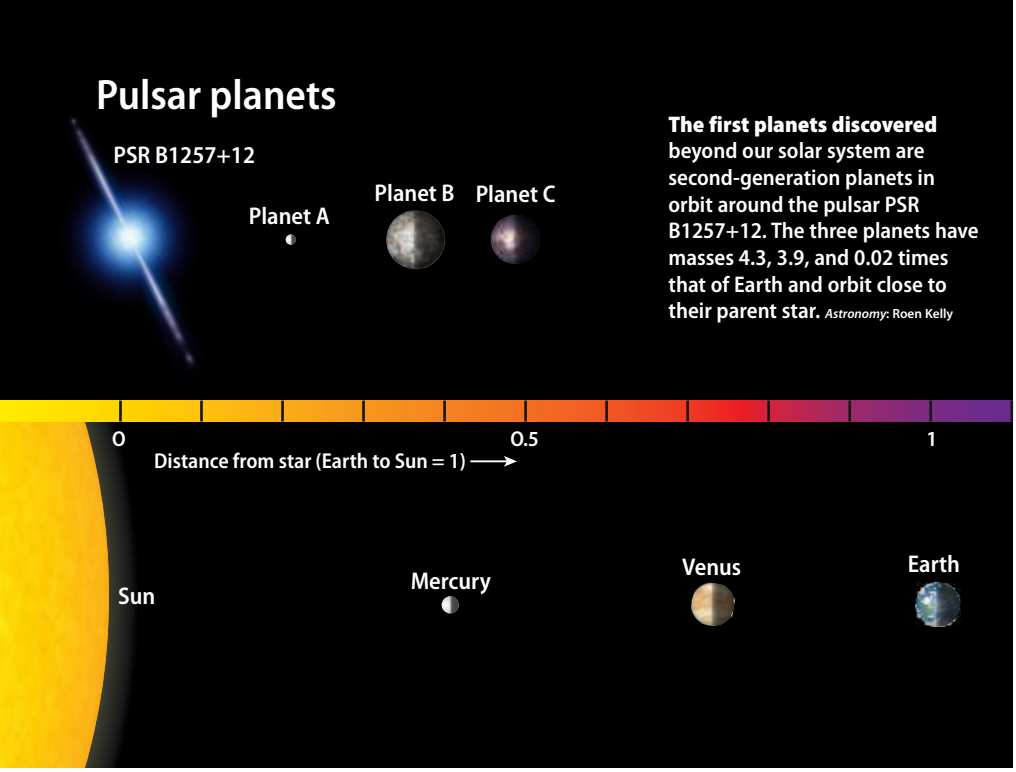
Newly vibrant worlds around dying stars offer one intriguing scenario for late-in-life planets, but true second-generation planets may provide an even more spectacular pathway. Despite their exotic beginnings, second-generation planets coalesce in much the same way as their first-generation cousins. Observations of dusty disks surrounding young stars as well as detailed theoretical simulations have strengthened the conventional wisdom about how planets form around newborn stars.

First, tiny grains of interstellar dust settle into a disk whirling around the star's equator. The grains then coagulate

Ray Villard *is the news director for the Space Telescope Science Institute in Baltimore.*



When the Sun swells to a red giant, the outer solar system will experience spring for the first time. Here, a watery ocean covers the surface of Jupiter's moon Europa while earthlike weather patterns dominate the giant planet's atmosphere. Lynette Cook for *Astronomy*



The first planets discovered beyond our solar system are second-generation planets in orbit around the pulsar PSR B1257+12. The three planets have masses 4.3, 3.9, and 0.02 times that of Earth and orbit close to their parent star. *Astronomy:* Roen Kelly

to form rocks, which coalesce under the relentless pull of gravity to form asteroid-sized bodies. These planet embryos quickly sweep up the remaining dust along their orbital paths. As long as gas is available, the more massive embryos bulk up and become Jupiter-like worlds. Smaller or slower-forming embryos end up as terrestrial bodies like Earth, Mars, and Venus.

But the planet formation process in our galaxy appears so robust that a dust disk around a star at the end of its life can also produce planets.

The first clue came in 1991 when radio astronomers Aleksander Wolszczan and Dale Frail discovered planets around a pulsar designated PSR B1257+12. The pulsar — a neutron star that spins once every 6.22 milliseconds — formed when a massive star exploded and left behind this crushed remnant. It lies about 1,000 light-years from Earth in Virgo.

Wolszczan and Frail saw a complicated pattern of changes in the precisely timed radio bursts coming from the millisecond pulsar. The signal shifts indicate minute changes in the distance between the pulsar and Earth caused by the gravitational tugs of three orbiting bodies. The planets have masses 4.3, 3.9, and 0.02 times that of Earth.

At the time of the discovery, Wolszczan speculated that the planets formed in the aftermath of the supernova. Astronomers assumed that the explosion would have destroyed or ejected any original planets. Ejected first-generation planets would be orphans left to drift through the galaxy as the neutron star and its swirling disk streaked across space following a kick from the supernova explosion. A new generation of planets then formed around the runaway stellar remnant. Wolszczan suggested these late-in-life planets coalesced from the explosion's debris.

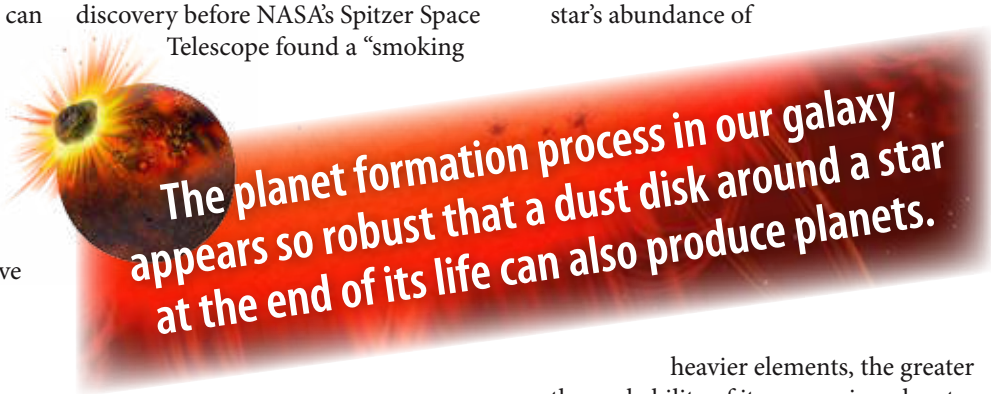
It took 15 years after the pulsar-planet discovery before NASA's Spitzer Space Telescope found a "smoking disk" surrounding a pulsar. In 2006, Spitzer detected the telltale infrared glow from a dusty disk orbiting 4U 0142+61, a pulsar located 13,000 light-years from Earth in Cassiopeia. The disk contains enough material to make 10 Earth-mass planets and orbits the pulsar at a distance from roughly 1 to 10 million miles (1.6 to 16 million km).

Astronomers have two competing theories as to how such disks form. In one, some of the supernova's debris fails to reach escape velocity and falls back toward the stellar remnant. In doing so, it forms a comparatively small disk no more than 100 million miles (160 million km) across and weighing about one-tenth of the Sun's mass.

Alternatively, the doomed star may have had a companion star that the explosion kicked into an eccentric orbit. Tidal forces from the neutron star's powerful gravity would tear the companion into a disk if it ventured near the collapsed object. This scenario fits the situation for PSR B1257+12, where the recoil from the supernova explosion launched the pulsar at an incredible speed of 500,000 mph (800,000 km/h).

However, the tidal-disruption model predicts Earth-mass planets would lie between about 200 million and 600 million miles (320 to 970 million km) from the pulsar. This is not true for PSR B1257+12. All three planets lie within 50 million miles (80 million km) of the pulsar, a value predicted by the fallback theory. Needless to say, astronomers have yet to reach a consensus on how the pulsar planets formed.

Many astronomers think that the debris disk would be rich in elements heavier than helium — the building blocks of new planets. Studies of nearby Sun-like stars show that the higher a star's abundance of heavier elements, the greater the probability of its possessing planets.


The planet formation process in our galaxy appears so robust that a dust disk around a star at the end of its life can also produce planets.

Carbon planets

Even stars with masses similar to the Sun could develop planets after they have evolved through the red giant stage and settled down as white dwarfs. Such second-generation planets could form in binary white dwarf systems that may or may not have had planets originally. In 2005, Mario Livio and his colleagues Jim Pringle of Cambridge University and

A dead civilization beams its history into the cosmos from an orbiting radio beacon. All civilizations must one day face a similar doomsday scenario.
Lynette Cook for *Astronomy*

Kenny Wood of the University of St. Andrews in Scotland proposed that late-in-life planets could be born from the mergers of white dwarfs.

The scientists noted that such mergers are an inevitable outcome of the evolution in some binary systems. They predicted that a carbon-rich disk would form from the tidal disruption and ultimate merger of two white dwarfs. The disk would be only about 200 million miles (320 million km) across and contain slightly less than 1 percent of the Sun's mass. Carbon-rich planetary embryos would form, and they might bulk up on surrounding gas to become gas giant planets.

Observational evidence for such a merger exists in GD 362. A dusty disk surrounds this massive white dwarf, which shows a spectrum that suggests it is accreting heavier elements. The disk likely comes from the breakup of a white dwarf companion or the tidal disruption of a large asteroid.

Marc Kuchner of NASA's Goddard Space Flight Center and Sara Seager of MIT propose that Earth-sized carbon planets could form out of shredded white dwarf debris. They would be tough little planets with tarry surfaces of carbides or even diamond. The atmosphere of a carbon planet might include nitrogen, ammonia, carbon monoxide, methane, and other hydrocarbons. The surfaces might have oceans of ammonia mixed with metals and organic material. Liquids such as ammonia or formaldehyde could work as solvents for biological processes, though they would operate under a different biochemistry than that on Earth.

Delaying doomsday

Both first- and second-generation planets ultimately face destruction. And any civilizations that arise on these planets must escape or perish. A 2001 study by Don Korycansky of the University of California at Santa Cruz and colleagues describes a massive, high-stake, high-reward astroengineering project: transforming Earth into a spaceship to delay doomsday.

Their basic idea uses gravitational assists from a smaller solar system body to transfer orbital energy from Jupiter to Earth. This life-and-death interplanetary billiards game would enlarge Earth's orbit so that it keeps getting nudged ever farther from the Sun.

To accomplish this transfer, the team envisions putting a main-belt asteroid or Kuiper Belt object on a highly elliptical orbit that would repeatedly pass near both Earth and Jupiter. In the same way a spacecraft can gain or lose energy by passing near a planet, the object would transfer energy from Jupiter to Earth.

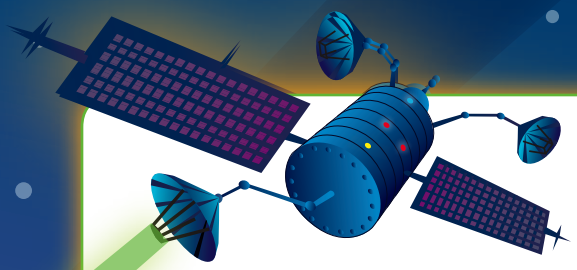
In the 1955 short story *The Star*, Arthur C. Clarke described a voyage to a supernova remnant where the crew discovers a lone surviving planet far from the exploded star. An intelligent race, foreseeing the coming apocalypse, creates a vast archive of its civilization for future visitors to find. Likewise, in James Gunn's 1972 novel *The Listeners*, an extraterrestrial civilization builds an automated radio beacon that broadcasts a record of the civilization's history to Earth-based SETI researchers.

Perhaps such is the fate of extraterrestrial civilizations scattered across the galaxy. But the conditions for planetary birth, survival, and rebirth seem common throughout a cosmos that, ironically, is indifferent to maintaining planetary paradises for very long. Nevertheless, the fundamental physics of the universe seems adept at rebuilding entire planets from the ashes of star death.

Watch an animation of planets starting to form in a dust disk created by a supernova at www.Astronomy.com/toc.

Invasion Of The Robotic Telescopes

Astronomy: Jay Smith and Chuck Braasch



Step aside, puny humans!

Faster and smarter telescopes are taking over much of the nightly drudgery of astronomical research. Soon they may make their own discoveries. **by Daniel Pendick**

It's hard to get a good night's sleep in the age of robotic astronomy. On March 18, 2008, Joshua Bloom was already in bed when his iPhone started to jangle with incoming text messages. The time was 11:13:06 P.M. in Berkeley, California, where Bloom is an astronomer at the University of California.

The messages told him that a burst of gamma rays had reached Earth at 11:12:49 P.M. — just 17 seconds earlier. Somewhere beyond the Milky Way, a massive star had collapsed to form a black hole. The dying star's sudden release of radiation is known as a gamma-ray burst, or GRB.

The strange thing is, no human astronomer had called Bloom's cell phone. It had come from a system Bloom set up for the Peters Automated Infrared Imaging Telescope (PAIRITEL) in Arizona. PAIRITEL had triggered automatically on a message sent to Earth by NASA's Swift telescope. The message included the GRB's sky coordinates.

PAIRITEL's motor drives whirred in the night as the scope slewed over to the burst. The race was on to learn as much as possible about the new GRB.

Welcome to the fast-paced world of "time-domain astronomy," in which celestial events evolve so quickly that only robots can keep up with them. Many robotic telescopes already come equipped with programs enabling them to communicate among themselves freely and organize follow-up observations of new sky events.

Futuristic multibarrel telescopes form part of the Los Alamos National Laboratories' RAPTOR robotic network. The instruments scan the sky from clamshell enclosures located at a remote observing site in the Jemez Mountains of northern New Mexico. LeRoy N. Sanchez (LANL)

The next generation of robotic telescopes may also make original discoveries. To do that, they will have to be smart enough to recognize things no one has seen before — the kind of strange first-ever events that make astronomers raise their eyebrows and say, "Hmmm . . . that's odd."

Where does this leave humans? Architects of the robot revolution say it will reduce the time-consuming drudgery of collecting data and free astronomers to advance science faster and more creatively. At the same time, they admit, many future astronomers may never experience the romance of "going to the mountain" for extended periods of dark-sky observing and contemplating the cosmos.

Banished from the dome

The classic image of observational astronomy is a scientific insomniac squinting into an eyepiece far into the night. But eyepieces are long gone, replaced with electronic imaging chips, spectrographs, and other sensors. Now robotic systems are removing some of the astronomers, too.

Computer software and hardware can perform most of the traditional tasks that once required intelligent "wetware" — astronomers, that is. This includes opening the observatory dome, monitoring sky conditions, pointing and focusing on the target, switching instruments, and collecting, preprocessing, and transmitting data.

Many small- to medium-sized telescopes once tended by people now run themselves and provide the same benefit. "To me, robotic telescopes are about extracting the astronomer from the traditional use of telescopes," Bloom says. "It allows them to work with the same instruments and facilities but in a way that is less labor intensive."

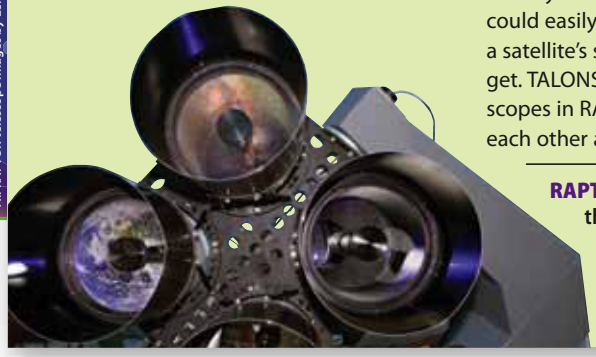
Dark-sky minutes are precious, and scheduling software allows robots to make the most of every moment. A software-based technique called "queue scheduling" allows automated telescopes to respond to changing conditions. "The use is optimized," Bloom says. "We dial in a variety of projects, all with different priorities and all with different requirements of time on the telescope. Then the telescope just wakes up at dusk, runs a scheduling program, and then everyone gets their e-mail in the morning."

Astronomers seize the sky with RAPTOR

Researchers at Los Alamos National Laboratory in New Mexico have created innovative telescopes for a robotic network known as RAPTOR: Rapid Telescopes for Optical Response. Like other birds of prey, the system monitors its surroundings until it finds its target — then seizes upon it.

Project leader Tom Vestrand modeled the first RAPTOR array after human vision. Four camera lenses with digital imaging chips provided a wide-field view of the sky, much like the eyeball's peripheral vision. A central, high-powered lens zoomed in on objects caught in the array's peripheral vision, mimicking the function of the eye's central detail-oriented fovea region.

The first RAPTOR network consisted of two foveal arrays, one at the Los Alamos campus and one 24 miles (38 kilometers) away in the Jemez Mountains of northern New Mexico. The separation gives RAPTOR stereovision. RAPTOR's central nervous system — the Telescope Alert Operations Network, or TALONS — triangulates between the two observing sites to exclude targets closer than the Moon. The night sky is full of stray sources of optical light. The system could easily mistake the glint of sunlight off a satellite's solar panel for a bona fide target. TALONS also enables the robotic telescopes in RAPTOR to communicate with each other and outside robotic networks.



RAPTOR-T's four telescopes focus on the same sky location. The array simultaneously observes the object in four colors (wavelengths) of visible light.

All RAPTOR telescope images by LeRoy N. Sanchez (LANL)

Tom Vestrand (left) and Los Alamos astrophysicist Przemek Wozniak with RAPTOR-Z, a fast-response telescope.

RAPTOR was born in the search for afterglows of visible light from gamma-ray bursts (GRBs), intense radiation flashes that originate with colliding or collapsing stars. In 2002, RAPTOR's foveal telescopes caught the early optical afterglow from a GRB while operating autonomously.

The RAPTOR team has continually added new instruments to the flock, mostly based at the dark Jemez Mountains site:

- **RAPTOR-T** for "technicolor" consists of four 0.4-meter telescopes on a rapidly slewing mount. This array simultaneously collects four different colors of light from the same target.

Catching the bumps

Having to observe fleeting events has brought more and more robots into astronomy. "These are things that are going bump in the night," Bloom says. "GRBs challenged the system. Every second really counted." Other bumps in the night include supernovae (exploding stars), asteroids, variable

internationally in 2006. Unlike the previous generation of astronomical telegrams, VOEvent messages need no human translator. The robots listen for alerts every second of every day. When something happens, they respond.

The telescopes are talking

- **RAPTOR-Z** for "zippy" is a single 0.5-meter telescope that can slew to any sky location in less than 5 seconds. Its camera collects 10 images per second to document fast-changing events.
- **RAPTOR-S** is a 0.4-meter telescope, also with a fast-slewing mount and rapid-imaging chip.
- **RAPTOR-K** carries 16 separate cameras to image large chunks of the sky in one gulp. By scanning back and forth, RAPTOR-K can image the entire sky visible to it every 5 minutes. It perceives sources as dim as 16th magnitude on the astronomical brightness scale. That means it can image a total of 100 million unique optical sources per scan.

The first RAPTOR telescope had four small lenses for performing an all-sky survey and a central telephoto lens for detailed views of particular targets.

The Los Alamos team continues to push robotic telescope technology, fine-tuning the reflexes of its growing flock of RAPTORS. "We have been experimenting with vibration sensors that can recognize mechanical problems before failure," Vestrand says. "Features like that would allow the network to recognize the emerging problem and redirect the load to minimize the use of that telescope until it can be serviced."

Ultimately, Vestrand imagines RAPTOR's instruments and network architecture will form the basis of a global "Thinking Telescope." Artificial-intelligence software that learns more about the sky every night and stores that knowledge in huge databases could eventually enable the Thinking Telescope to start making its own original discoveries.

Los Alamos researcher James Wren works on the 16-lens wide-field RAPTOR-K array.

In a way, RAPTOR has already had its first eureka moment. On February 6, 2006, the network called Los Alamos astrophysicist Przemek Wozniak on his cell phone to report the rising optical afterglow from a GRB that had ceased pumping out gamma rays some 50 minutes earlier.

The "rebrightening" was a first-time observation — one so unexpected that Vestrand admits he might have dismissed it as a mistake. "Probably, if I had been sitting at the telescope, I would not have even bothered to look at the GRB." — *D. P.*

LCOGT is the brainchild of former Google software executive Wayne Rosing. After holding high-level positions at Apple and other industry leaders since the 1970s, Rosing returned to his lifelong love of astronomy. The foundation he funded is paying for LCOGT's design, construction, and deployment. LCOGT's scientific director is astronomer Timothy Brown, one of the first scientists to observe extrasolar planets in the 1990s. Brown is also an adjunct professor in the physics department of the University of California at Santa Barbara, LCOGT's academic partner.

LCOGT's telescopes will follow a standard design. The current deployment plan includes a minimum of five telescope clusters to provide continuous coverage of the sky. Each cluster will include 1-meter and 0.4-meter telescopes — at least two of each type. The 1-meter telescopes are primarily for science. LCOGT will make time on the 0.4-meter instruments available to schools for educational use.

Two cluster sites are already established. The sites currently host the 2-meter Faulkes South Telescope at Siding Spring Observatory in Australia and its twin, the Faulkes North Telescope in Haleakala, Hawaii. Las Cumbres owns both instruments.

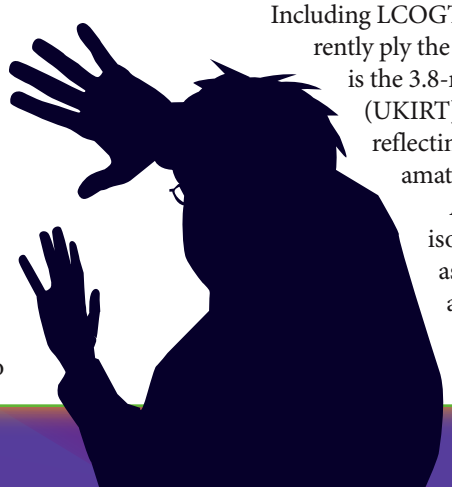
The Siding Spring cluster will cover the Southern Hemisphere — but only at night, of course. LCOGT will build two more clusters to provide continuous coverage of the Southern Hemisphere 24 hours a day. One site is Cerro Tololo Inter-American Observatory in Chile; the other is the South African Astronomical Observatory.

Building the Northern Hemisphere ring presents more of a challenge. Not enough space is available at Faulkes North for a full-sized cluster. LCOGT hopes to acquire a second site in Hawaii and one in the Canary Islands. These locations, roughly 12 hours apart in longitude, could provide continuous coverage of the northern sky.

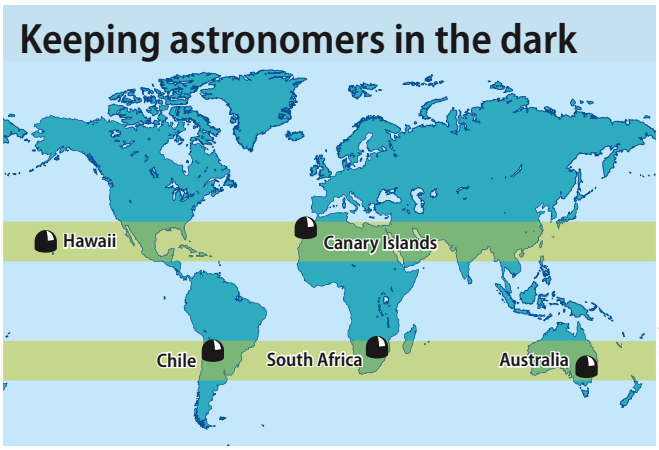
Initially, LCOGT will focus on extrasolar planet studies and observing stellar transients (mostly supernovae) outside our galaxy. The supernova observations are key to more precisely measuring the universe's expansion and understanding why it appears to be speeding up — among other cosmological questions. "Our hope is that by concentrating a lot of our resources on projects that are very demanding of observing time, we can actually do things that nobody else can do," Brown says.

The telescope Internet

Including LCOGT, less than a dozen robotic networks currently ply the night skies. The largest robotic light bucket is the 3.8-meter United Kingdom Infrared Telescope (UKIRT). Also pitching in is a gaggle of smaller reflecting telescopes, on par with the ones many amateur astronomers use.



At the cutting edge of robotic astronomy, isolated telescope networks are starting to assemble into a global web of networks. "It's a meta-network," says Alasdair Allan of the University of Exeter in England. "It's like the Internet for robotic telescopes." Allan



Astronomy: Jay Smith

The planned Las Cumbres Observatory Global Telescope includes two rings of robotic observatories. The scopes can hand off observations as the world turns, providing 24-hour access to the night sky.

is the lead programmer and co-founder of the eScience Telescopes for Astronomical Research (eSTAR) project, based at Exeter's Astrophysics Group and the Astrophysics Research Institute at Liverpool John Moores University.

The regular Internet functions because of universal rules and procedures, called protocols, that allow computers to exchange data. The eSTAR project is doing the same to connect the motley mix of technology and software in robotic networks. "Every telescope has its own dialect," Bloom says. "Just to get a telescope to go from point A to point B — there are hundreds of ways that is done."

To make it easier for robotic telescopes to hook up, eSTAR and various robotic observing projects formed the Heterogeneous Telescope Network (HTN). Allan and one of his former graduate students, Eric Saunders, created the HTN software "socket." It allows robotic telescopes to communicate. (Saunders now works on the LCOGT.)

Conversations between HTN telescopes occur via documents written in the remote telescope markup language, or RTML. Created in 1999 by scientists at UC-Berkeley, RTML is analogous to HTML, a computer code programmers use to create web pages.

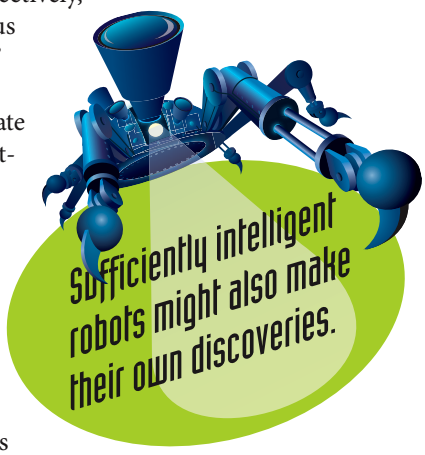
And what do the telescopes talk about? Observations, of course. As in: "Hi, I'm a telescope in California. I'm observing this supernova, but it's heading toward the horizon fast. Could anyone pick this up, take spectral data, and e-mail it to me?"

Some telescopes send back messages saying, "Sorry, my spectrograph is broken." Others retort, "Buzz off! You don't have any time allocated on our network." A few don't even respond at all — too busy with their own priority work tonight. But some telescopes do join the effort, allowing the HTN to collectively extend its members' ability to do astronomy.

Smarter scopes

Globally networked telescopes are also getting smarter and more independent thanks to goal-directed software programs eSTAR is developing called autonomous agents. "These allow HTN-enabled telescopes to carry out intelligent observing campaigns," Allan says. "The agent does stuff for itself. It gets better at doing stuff for itself. It can learn from the decisions it's made to see whether it has achieved its goal."

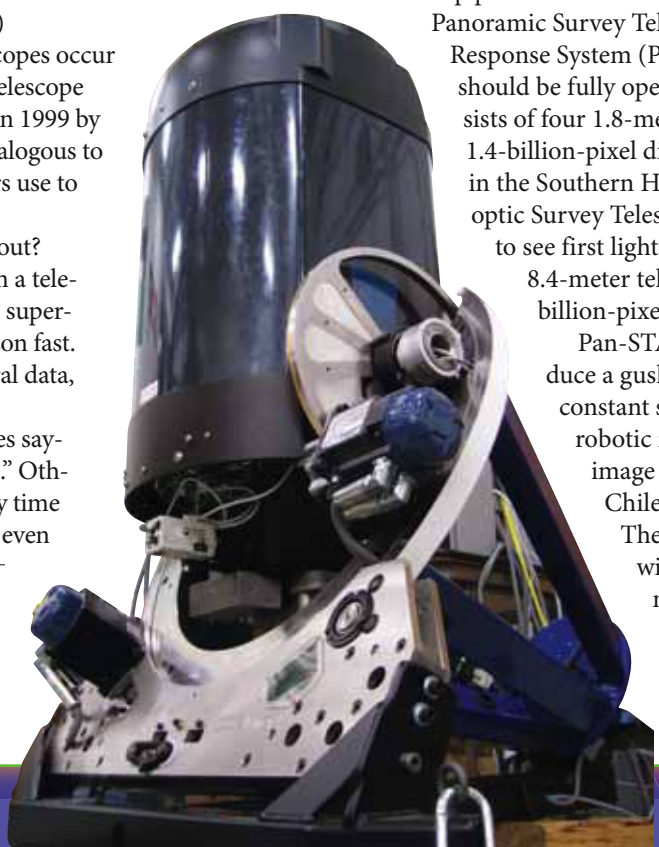
In the network, researchers are software agents making requests, just as the agents in individual telescopes can make requests of each other. Effectively, the telescopes' autonomous agents don't really "know" humans even exist.



After astronomers initiate a science project on the network, the robots can make many of the intermediary decisions on how to carry it out. For example, eSTAR's agents are already running an observing project known as RoboNet, which confirms discoveries of new extrasolar planets.

The need for smarter robotic networks is becoming more urgent. Soon new survey telescopes will start detecting more new bumps in the night than human astronomers can hope to keep pace with. In the Northern Hemisphere, the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) in Hawaii should be fully operational by 2012. It consists of four 1.8-meter telescopes, each with a 1.4-billion-pixel digital camera. Meanwhile, in the Southern Hemisphere, the Large Synoptic Survey Telescope (LSST) is scheduled to see first light in 2014. It sports a single 8.4-meter telescope attached to a 3.2-billion-pixel camera.

Pan-STARRS and LSST will produce a gusher of digital data — and a constant stream of alerts to trigger robotic networks. LSST alone will image the sky over its site in the Chilean Andes every 3 days. The data gusher, combined with robotic networks, will make many science projects possible that were pipe dreams before. For one thing, astronomers will multiply the cata-



At Las Cumbres Observatory's workshop in Goleta, California, astronomers assembled and tested this prototype 0.4-meter telescope. The observatory will ship the standard "production model" scopes to LCOGT sites around the world. LCOGT

log of type Ia supernovae, which provide a "standard candle" for measuring the size and expansion rate of the universe.

But astronomers anticipate having too many discoveries and too few telescopes to follow up on them. Robotic telescopes will have to be pickier about what they target. "Without the intelligence to make discriminating decisions, you're going to be swamped with the hundreds of thousands of possible targets to follow up every night," Allan says.

The age of robotic discovery?

Some astronomers believe robotic telescopes could do a lot more than follow up — if they only had the brains. Sufficiently intelligent robots might also make their own discoveries. Tom Vestrand, a researcher at Los Alamos National Laboratory in New Mexico, heads the Thinking Telescope Project. It's the next evolutionary step forward from RAPTOR, a high-tech robotic network Vestrand and his colleagues operate in New Mexico. (See box on page 30.)

Like humans, thinking telescopes will need the ability to identify celestial objects based on known categories — GRB versus supernova, for example. And a thinking telescope must also be able to tell when it's looking at something new.

Vestrand says robots can gain these powers through a technique called machine learning. As it observes new objects, the telescope compares them to a database containing everything it's seen up to that point. When a new target appears in its field of view, it will know.

But it will also know if a previously observed target is behaving differently. "It's easy to do change detection," Vestrand says. "It's much harder to recognize how important that change is. That's where the databases come in. You look at what's been the pattern for this object over the last several years. Has it done this before?"

Then, like a human astronomer, the telescope will need to decide what to do next. Should it observe the object's light at multiple wavelengths or just record a simple light curve? How often should it collect data? The system will need to learn from past experience and store the lessons for later use.

It may sound like robotic-telescope developers want to exclude members of their own species entirely, but that's not the case. Human intelligence will play a critical role. Allan is working on a way to connect astronomers to RoboNet and other eSTAR-driven efforts via iPhone.

"If they were standing in a bar, or whatever, they can actually monitor the ongoing observing program, and they can add human knowledge into the system," Allan says. "They can tell the agent, 'I think you've made a mistake. I think this is really important.' "

The workhorse science scopes in the Las Cumbres Observatory Global Telescope network have 1-meter-wide primary mirrors. They will all conform to a standard design similar to the one in this computer-generated concept. LCOGT

NASA/ESA/The Hubble Heritage Team (AURA/STScI)

The variable star V838 Monocerotis brightened dramatically in 2002, illuminating surrounding shells of dust and gas, as shown in this Hubble Space Telescope image captured October 28, 2004. Powerful digital survey telescopes coming online soon may discover so many new variable stars every night that only intelligent robotic telescopes will be able to keep up with critical follow-up observations.

Going to the mountain

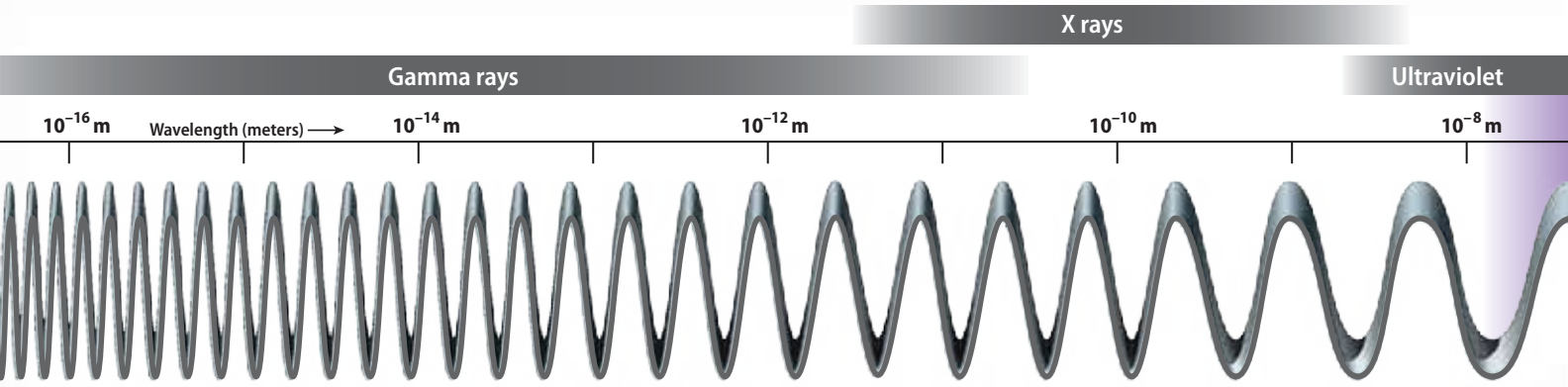
Astronomers will never completely part ways with their telescopes. Robotic technology has taken over some small- and medium-sized instruments, but nobody is even considering turning over the largest and most expensive light buckets on Earth to the machines. Complex instruments like the 10-meter Keck telescopes still need human tenders.

Also, students must at some point lay hands on real telescopes to learn how to be astronomers. "That's something we certainly don't want to lose," says Chris Smith, director of the Cerro Tololo Inter-American Observatory. "It is important for new astronomers to know what goes into the data. It's important to have at least some experience on the mountain so you understand what can go wrong."

On the plus side, robotic technology will ultimately give astronomers more time to figure out how the universe works. "It takes an awful lot of the day-to-day drudgery work out of it," says Exeter astrophysicist and eSTAR science team member Timothy Naylor. "This leaves the astronomer freer to think about what the actual data mean, rather than how they're going to acquire data."

Even so, replacing routine observing work by humans will inevitably take some of the romance out of astronomy. "There are a lot of astronomers," Smith says, "myself included, who will mourn the idea of not going to the mountain."

Find out how robotic telescopes discover planets outside the solar system at www.Astronomy.com/toc.



Light's dual personality

Is light a wave or a particle? Science says both.

by Liz Kruesi; illustration by Roen Kelly

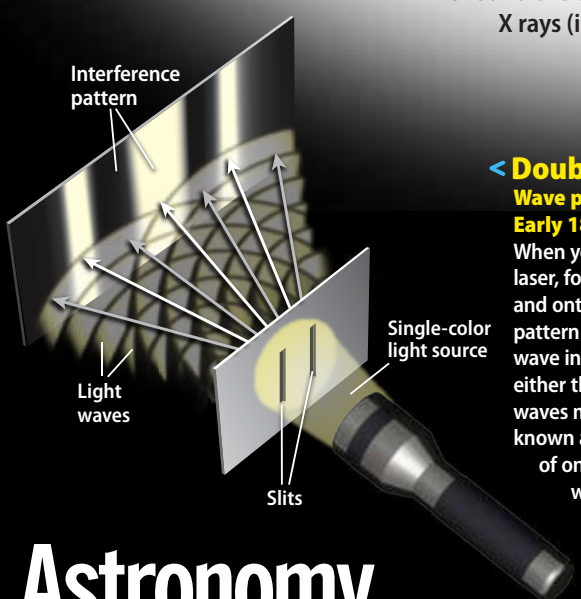
What exactly is light? We typically refer to the part of the electromagnetic spectrum that human eyes can see as "light." Visible light — like all radiation in the electromagnetic spectrum (X rays, microwaves) — can have characteristics similar to a wave (think of water ripples) and also a particle. This multiple personality is known as the wave-particle duality.

Depending on the electromagnetic radiation's energy level, certain properties are more pronounced. For example, at lower energies (in the microwave range), radiation takes on wavelike properties. At higher energies (such as X rays), radiation acts more like a particle, which is called a "photon," but it still exhibits wave properties. Numerous experiments in the 1800s and early 1900s showed this idea isn't too bizarre.

Prior to the early 1900s, physicists had determined visible light is part of the electromagnetic spectrum. At that time, they thought all radiation propagates as a wave. The double slit experiment and the discovery of X rays (including that they behave like visible light) seemed to solidify the wave nature of light. But within a decade, additional experiments cast doubt on light's wave properties. Physicists then had data — from both the photoelectric effect and the Compton effect (see diagrams at right) — that light exhibits particle properties.

And that's not all. While light has wave and particle properties, so does matter. The wave property isn't noticeable in large objects such as people and stars, but it is noticeable in subatomic particles — the building blocks that compose those larger objects. An object's momentum (which is related to its energy) is what governs whether its wavelike property will be apparent. The larger the momentum, the shorter the wavelength. A macroscopic object (such as a star) has a tiny wavelength — so small that it's impossible to see. But microscopic objects (electrons and photons) have little momentum, which means a longer wavelength and observed wave properties.

Liz Kruesi *is an associate editor of* Astronomy.

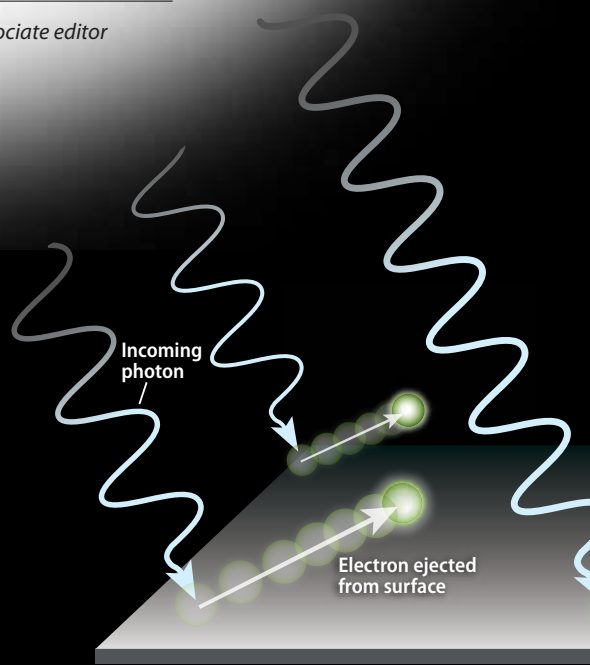


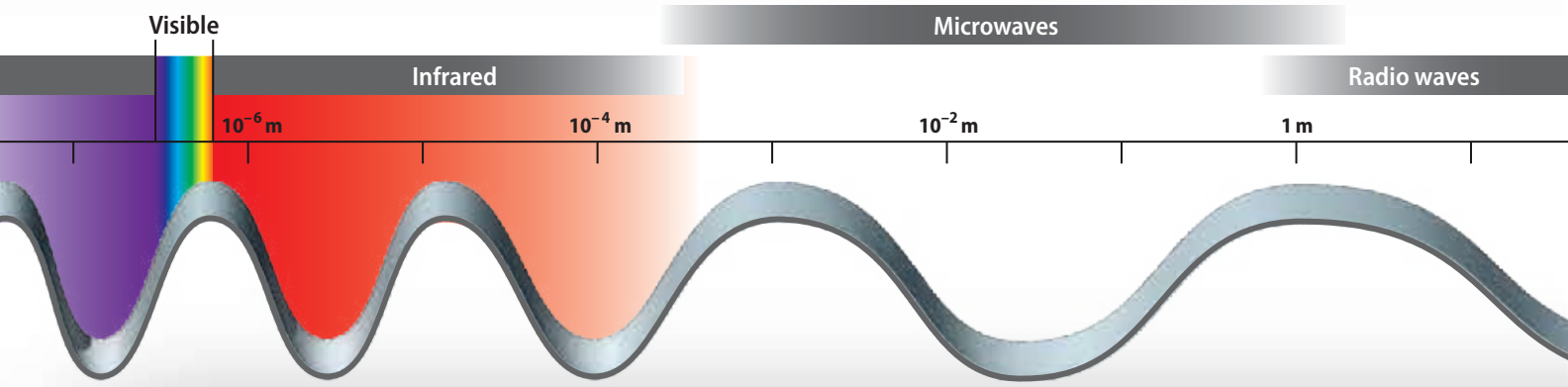
< Double slit with light

Wave properties

Early 1800s (Thomas Young)

When you shine light of one color (using a laser, for example) through two narrow slits and onto a screen, you will see an interference pattern on the screen. Light must act as a wave in order to have such a pattern. When either the peaks or valleys of intersecting waves meet up, they add together — this is known as constructive interference. If a peak of one wave and the valley of the other wave meet, they cancel each other and no signal is visible — this is called destructive interference.



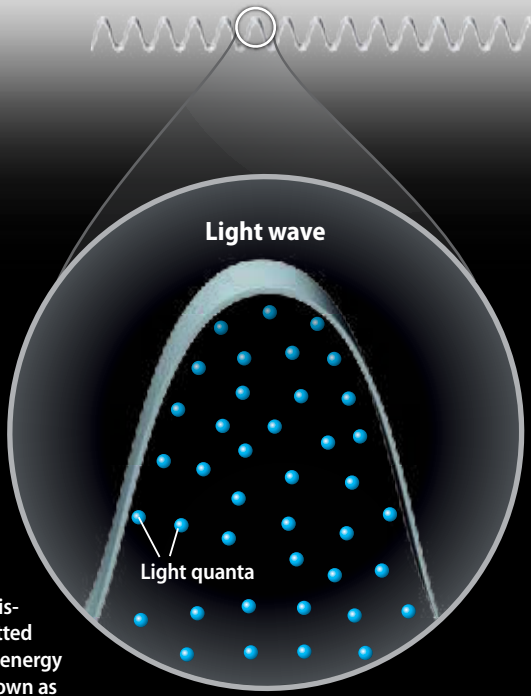


^ Electromagnetic spectrum

At lower energies, and therefore longer wavelengths, it's more appropriate to use the wave characteristics of light. At higher energies, one uses quantum physics and photons to explain an object's structure or movement.

> Perspective matters

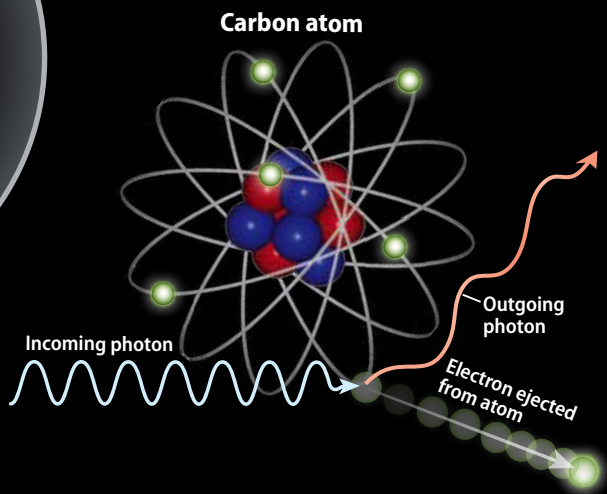
On a large (macroscopic) scale, light's properties appear wavelike, but as you zoom in and observe light on a smaller (microscopic) scale, you'll see particle characteristics. Radiation (light) is emitted and absorbed in packets of energy called light quanta, also known as photons. These light particles also possess wavelike properties.

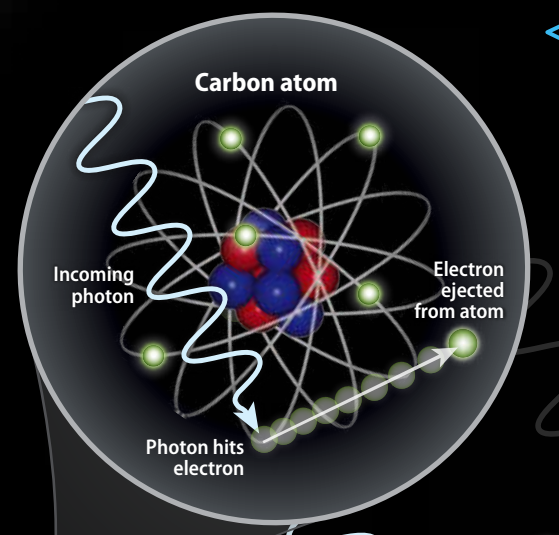


v Compton effect

Particle properties
1922 (Arthur Holly Compton)

In this experiment, a light particle, called a photon, collides with an electron and transfers some energy and momentum to the electron. The scattered photon then has a longer wavelength and therefore less energy. An electron could not scatter light if light had only wavelike properties.

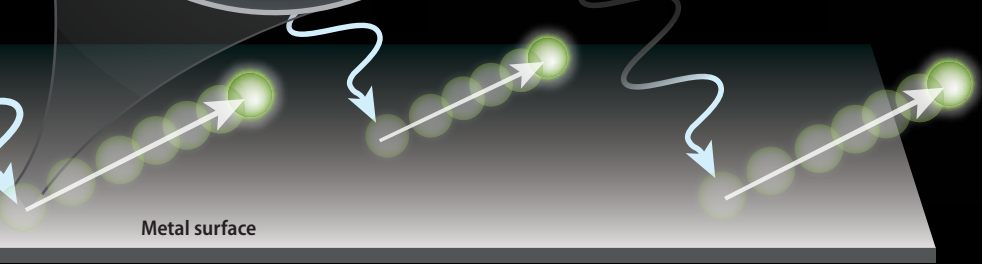


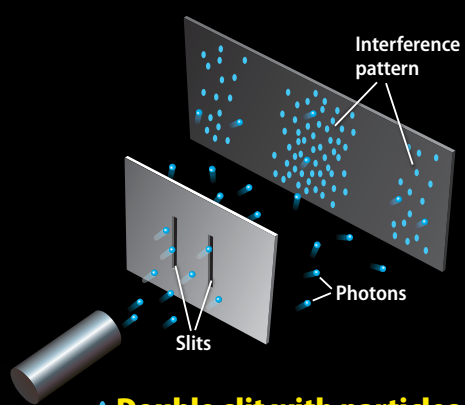


< Photoelectric effect

Particle properties
1905 (Albert Einstein)

This experiment showed that when incoming light hits a metal surface, the light knocks electrons out of the metal. The wave theory of light predicted that a higher intensity of incoming light should increase the energy of each ejected electron. Instead, scientists saw only an increase in the number of electrons emitted, not their energies. The particle nature of light explains this effect. When a light photon hits the metal — and if the photon has a particular energy — an electron will absorb all of the photon's energy and be ejected from its atom. With an increase in light intensity, only the number of photons changes, not a photon's energy. Thus the resulting electron's energy remains the same.





^ Double slit with particles

Wave properties
1920s

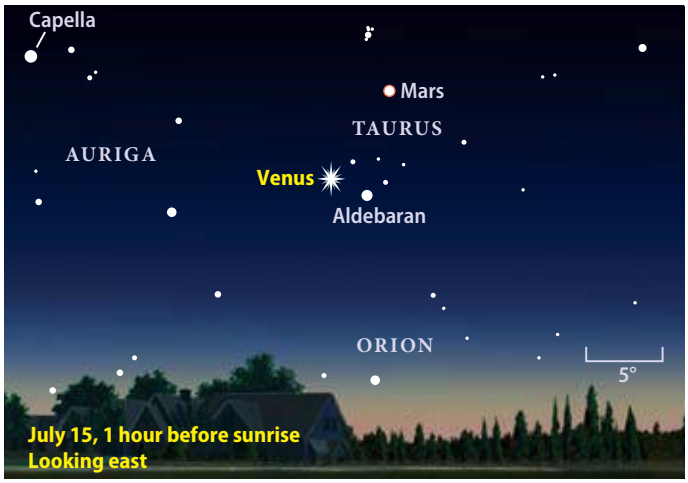
Scientists have performed the double slit experiment with individual photons, electrons, and protons. In all cases, scientists observe an interference pattern on the screen. This means that matter exhibits wavelike characteristics.

The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

July 09

Totality crosses eastern Asia



Venus highlights Taurus this month, putting a bright spotlight on the Bull during the predawn hours. Venus shines 100 times brighter than Taurus' luminary, 1st-magnitude Aldebaran. *Astronomy:* Roen Kelly

There's an old cliché that says the early bird catches the worm. Well this month, the phrase holds true for skywatchers. Some of the best planetary sights occupy the predawn sky. Venus and Mars pair up in the east among the conspicuous stars of Taurus the Bull. A waning crescent Moon joins the action around midmonth.

As this scene rises, Jupiter dips in the southwest after a nearly full night of visibility. For those of you uninterested in chasing worms, the evening sky offers some good final views of Saturn before the ringed world succumbs to the Sun's glare in August.

Let's begin our planet tour, as usual, in the early evening sky. As July begins, **Saturn** remains above the western horizon until midnight. Your best views will come as twilight draws to a close. Regulus, Leo's brightest star, lies 15° to Saturn's lower right. If you draw an imaginary line from Regulus through Saturn and extend it into the southwestern sky, you'll find Virgo's luminary, Spica. All three objects shine with nearly the same brightness: Saturn at magnitude 1.0, Regulus at magnitude 1.4, and Spica at magnitude 1.0.

You may not see Saturn's rings after early July. First, the rings' tilt to our line of sight narrows from 3.2° to 1.9° during July. Second, Saturn sinks lower in the evening sky late in the month, which means you have to observe it through more of Earth's turbulent and image-degrading atmosphere. The result: Saturn's reputation as the most beautiful planet will be in serious jeopardy.

Saturn's rings will soon go dark. They will be edge-on to the Sun in early August, so the Sun can't illuminate them. The rings turn edge-on to Earth in September, but Saturn will be too close to the Sun in our sky to observe then.

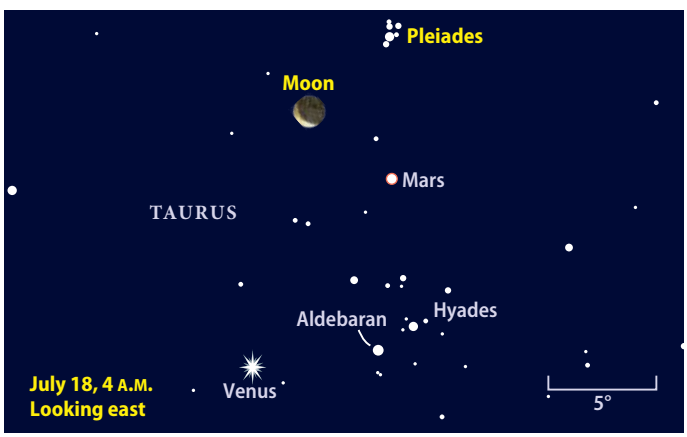
Although the rings may be hard to see this month, Saturn's flattened disk won't be. The planet's equator measures 17" across in July while its polar diameter spans 15".

Saturn's bright moons also continue their impressive displays. The planet's biggest moon, Titan, remains the highlight. Once each orbit, Titan and its shadow transit Saturn's face. And half an orbit later, the massive planet eclipses Titan. Three events favor North American observers in July. The first occurs July 1. Titan's shadow falls on Saturn beginning at 10:49 P.M. EDT, although it will take several minutes before the shadow becomes noticeable. The transit continues long after Saturn sets.

— *Continued on page 41*

36 Venus climbs high before dawn
36 The Moon joins the Pleiades
41 Meteor watch
41 Rising Moon
42 When to view the planets
42 Titan's shadow crosses Saturn
42 Comet search
43 Locating asteroids
43 Total eclipse of the Sun

Visible to the naked eye
Visible with binoculars
Visible with a telescope



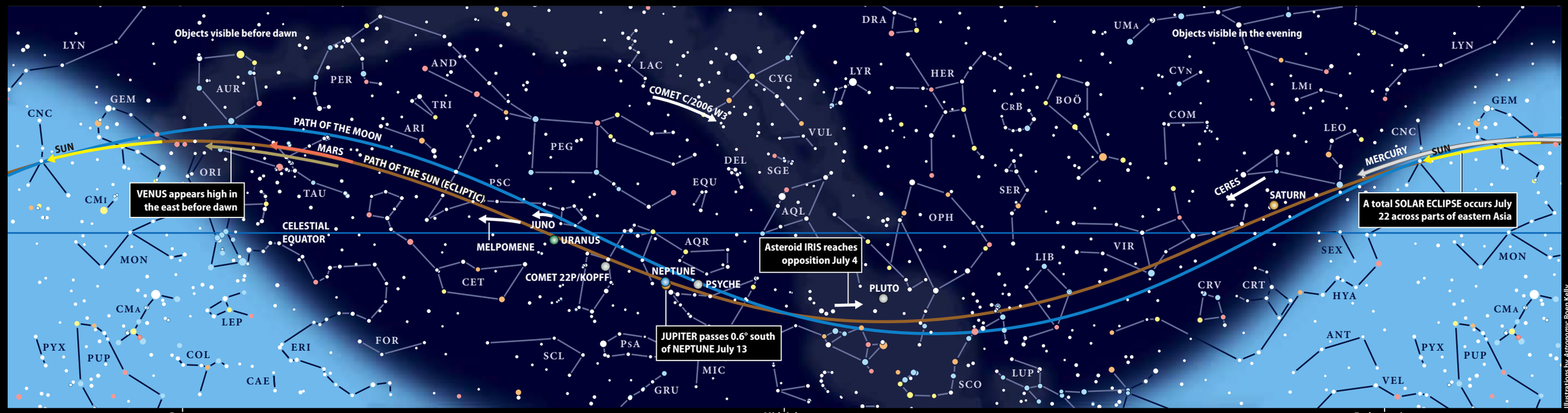
The Moon lies near the Pleiades cluster before dawn July 18. To make the scene more spectacular, Venus and Mars appear close by. *Astronomy:* Roen Kelly

Planets in July 09

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

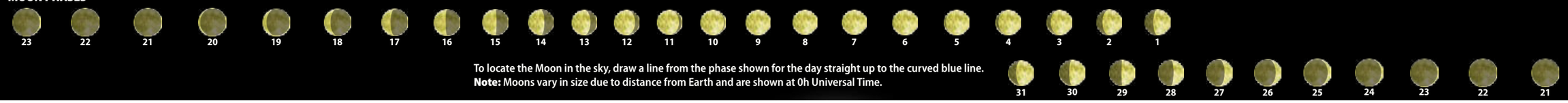
Astronomy magazine

Path of the planets



Illustrations by *Astronomy*: Roen Kelly

MOON PHASES

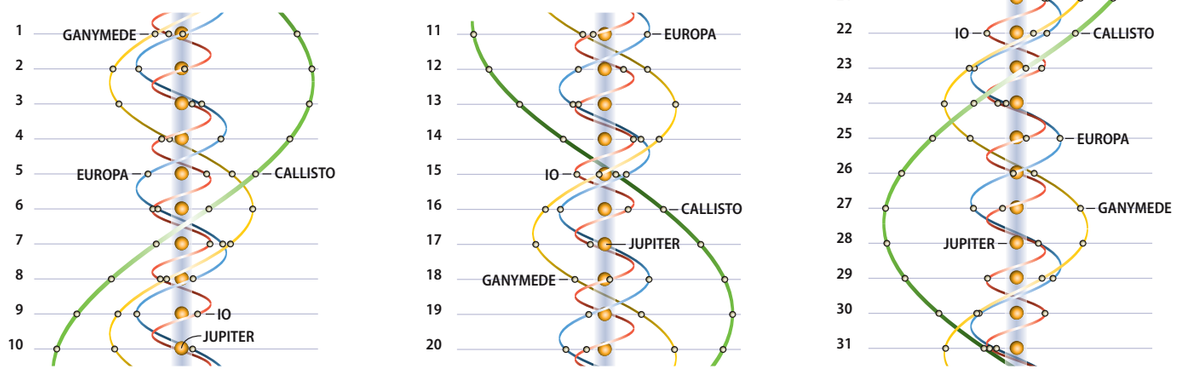


To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	July 1	July 15	July 15	July 15	July 15	July 15	July 15	July 15	July 15
Magnitude	–1.0	–4.1	1.1	8.8	–2.8	1.1	5.8	7.8	13.9
Angular size	5.7"	16.6"	5.1"	0.4"	47.3"	16.7"	3.6"	2.3"	0.1"
Illumination	80%	67%	92%	97%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.178	1.008	1.838	2.943	4.167	9.969	19.630	29.174	30.731
Distance (AU) from Sun	0.325	0.727	1.429	2.589	5.050	9.424	20.098	30.029	31.675
Right ascension (2000.0)	5h35.7m	4h37.1m	3h59.6m	11h44.9m	21h52.5m	11h17.4m	23h48.1m	21h52.8m	18h05.4m
Declination (2000.0)	22°45'	19°41'	20°02'	11°04'	–13°57'	6°46'	–2°09'	–13°18'	–17°43'

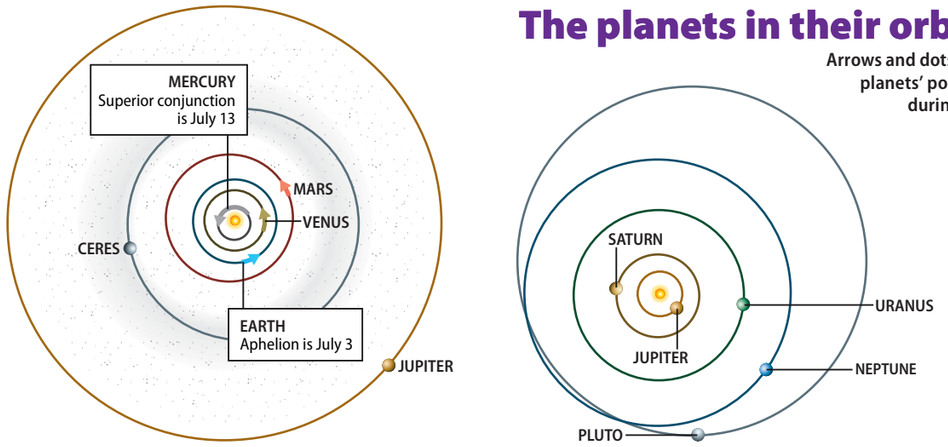
Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

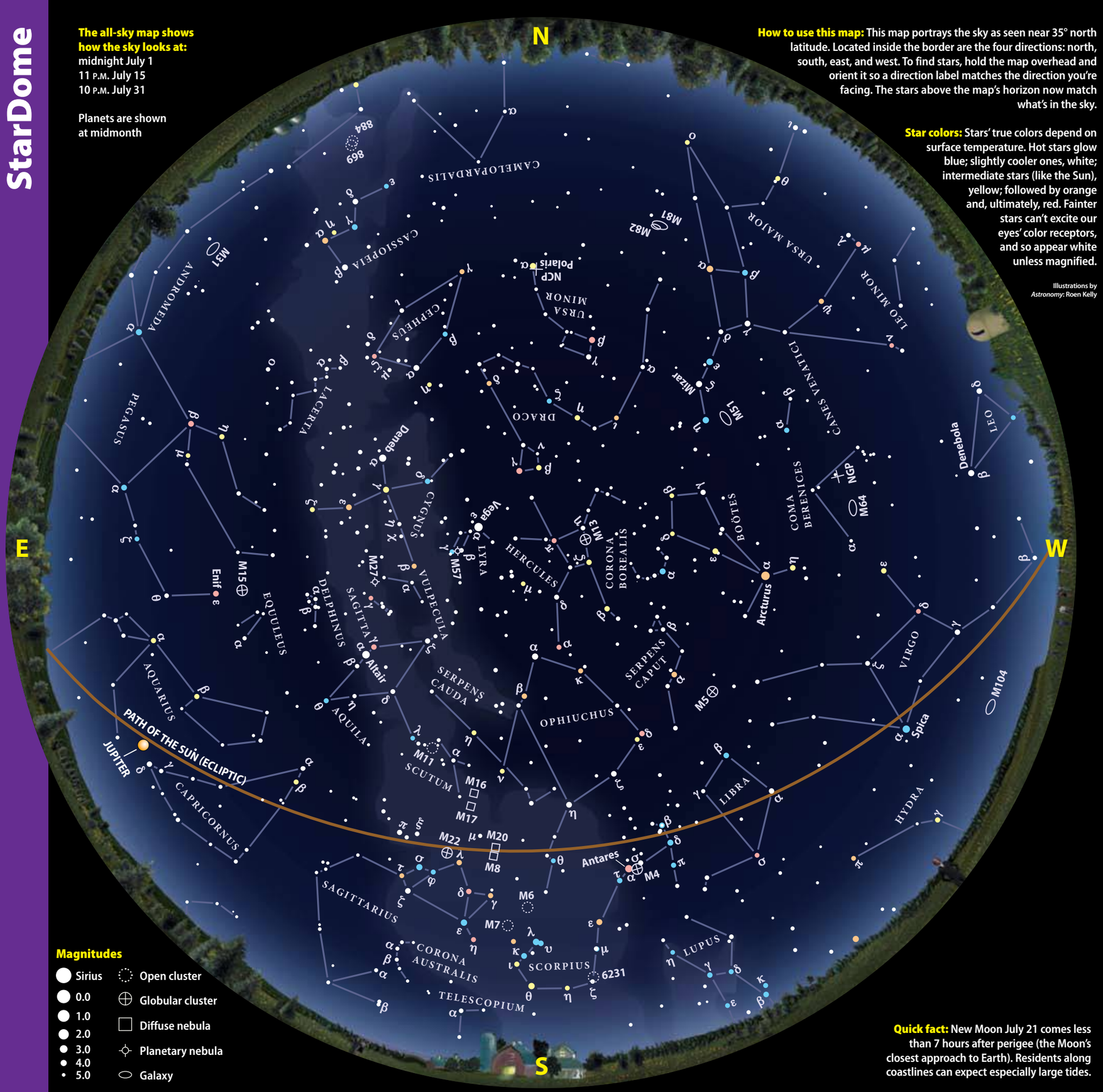
Arrows and dots show planets' positions during July.



StarDome

The all-sky map shows how the sky looks at:
midnight July 1
11 P.M. July 15
10 P.M. July 31

Planets are shown at midmonth



How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly

Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: New Moon July 21 comes less than 7 hours after perigee (the Moon's closest approach to Earth). Residents along coastlines can expect especially large tides.

July 09

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Calendar of events

1 Uranus is stationary, noon EDT

3 Earth is at aphelion (94.5 million miles from the Sun), 10 P.M. EDT

4 Asteroid Iris is at opposition, 5 A.M. EDT

The Moon passes 0.5° north of Antares, 6 A.M. EDT

7 Full Moon occurs at 5:21 A.M. EDT; penumbral lunar eclipse

The Moon is at apogee (252,421 miles from Earth), 5:39 P.M. EDT

10 The Moon passes 4° north of Jupiter, 6 P.M. EDT

The Moon passes 3° north of Neptune, 6 P.M. EDT

13 The Moon passes 6° north of Uranus, 8 A.M. EDT

Jupiter passes 0.6° south of Neptune, 3 P.M. EDT

Mercury is in superior conjunction, 10 P.M. EDT

14 Venus passes 3° north of Aldebaran, 2 P.M. EDT

15 Last Quarter Moon occurs at 5:53 A.M. EDT

18 The Moon passes 5° north of Mars, 8 A.M. EDT

19 The Moon passes 6° north of Venus, 1 A.M. EDT

21 The Moon is at perigee (222,117 miles from Earth), 4:14 P.M. EDT

New Moon occurs at 10:35 P.M. EDT

Special observing date

22 A total solar eclipse graces the sky above a narrow path that cuts across eastern Asia and the western Pacific.

25 The Moon passes 7° south of Saturn, 11 A.M. EDT

27 Mars passes 5° north of Aldebaran, 7 A.M. EDT

Southern Delta Aquarid meteor shower peaks

28 First Quarter Moon occurs at 6:00 P.M. EDT

31 The Moon passes 0.5° north of Antares, noon EDT

See tonight's sky in Astronomy.com's STARDOME

Astronomy magazine

— *Continued from page 36*

Saturn eclipses Titan July 9 starting at 10:58 P.M. CDT. (The planet has already set along the East Coast.) At this time, Titan lies just southeast of Saturn's disk. It will take 16 minutes for Titan to move completely into the shadow and disappear from view.

Another nice event occurs July 17. At 10:00 P.M. EDT, Titan's shadow starts crossing Saturn's disk. For the rest of the evening, the shadow tracks slowly across the planet's north polar region. The pitch-black shadow appears distinct against Saturn's bright cloud tops.

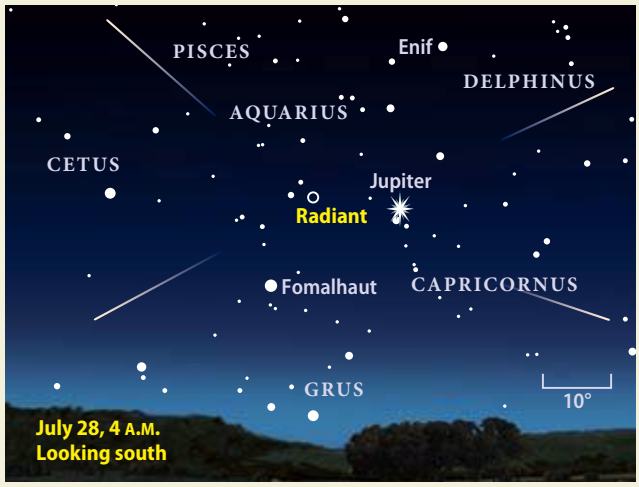
July is a great time to track down everyone's favorite dwarf planet, **Pluto**. It reached opposition in late June, so it now lies high in the south during the late evening hours. Pluto lies among the background stars of northern Sagittarius, some 4° northwest of Mu (μ) Sagittarii.

At magnitude 13.9, however, Pluto isn't easy to find. If you want to see it visually through the eyepiece, you'll need a dark observing site, a telescope at least 10 inches in aperture, and a chart showing stars down to 15th magnitude. Once you've located the correct star field, try to spot the dwarf planet. If you can't tell which dot is Pluto, sketch the field and return to it a night or two later. The object that has changed position is Pluto.

As Saturn sets in the west, **Jupiter** rises in the southeast. The solar system's largest planet shines at magnitude –2.8, and it dominates the southern sky during the overnight hours. Jupiter lies in eastern Capricornus just 2° north of the 3rd-magnitude star Delta (δ) Capricorni. This region lies high in the south around 3 A.M. local daylight time in mid-July. Higher altitudes make for better views through a telescope because Jupiter's light traverses less of Earth's turbulent atmosphere.

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire.* **Alister Ling** *is a meteorologist for Environment Canada in Edmonton, Alberta.*

Meteor watch



Meteors will rain from Aquarius in late July. The Southern Delta Aquarid shower should peak before dawn July 28. *Astronomy*: Roen Kelly

Meteor season starts to rev up

July begins a 2-month period of heightened meteor activity. A few small showers grace the night sky while one of the biggest — the Perseids — begins to ramp up as the month winds down. A Last Quarter Moon will mar the Perseids' peak in August, but late July gives us a good look at the early ones. The best views of meteors come after midnight (because they then hit Earth's leading hemisphere) when the Moon is out of the sky. The Moon cooperates from a few days before New Moon (July 21) until month's end.

The top July meteor shower should be the Southern Delta Aquarids. They peak the night of July 27/28, so the best views will come before dawn on the 28th. The shower remains active several days before and after. At the peak, you can expect to see up to 10 meteors per hour from a dark site. Those who live farther south, where the radiant lies higher in the sky, will see more meteors.

Rising Moon

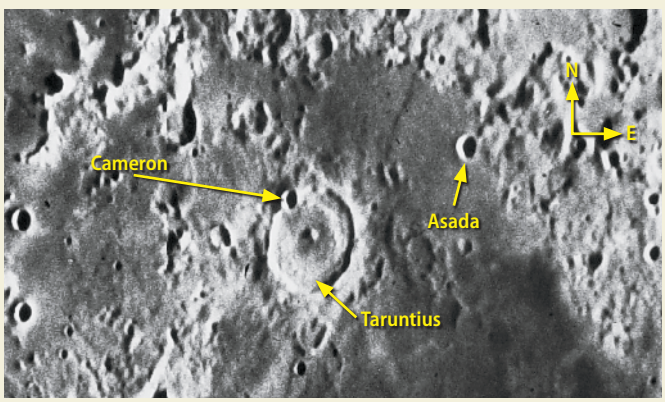
Spy a large lunar crater

To naked-eye observers, the most obvious characteristic of July's Moon is its yellowish cast and low track across the southern sky as it waxes to full phase (July 7). Because Earth's atmosphere scatters more blue light than other colors, it skews the color balance toward the red end of the spectrum. The closer to the horizon an object lies, the stronger its yellow hue.

If this is your first year of Moon watching, be sure to notice how far Mare Crisium appears from the eastern limb during July's first week. Night after night, this conspicuous dark expanse slowly turns back toward the lunar limb as our viewing angle changes.

Just south of Mare Crisium lies an even bigger ocean of frozen lava known as Mare Fecunditatis. The prominent crater Taruntius sits on the Sea of Fertility's northern shore. This crater's well-defined rim and faint ray system suggest it is relatively young. Still, it's old enough that lava rose up through its cracked floor and filled much of the interior. Taruntius was named after a famous Roman mathematician and philosopher.

An even younger crater lies on Taruntius' northwestern edge. Cameron measures 7 miles across while Taruntius spans 35 miles. Smaller impact bodies tend to leave sharp bowl-shaped craters like Cameron on the Moon's face. Another splendid example is Asada, perched east and a little north of Taruntius near the mountainous shoreline of Mare Fecunditatis. During July's first week, the Sun shines down on Asada, making its bowl shine as if under a spotlight.



Lurking in Mare Fecunditatis, the 35-mile-wide crater Taruntius sports a sharp rim and modest central peak. The small crater Cameron sits on Taruntius' northwestern edge. *Consolidated Lunar Atlas*/UA/LPL

When to view **the planets**

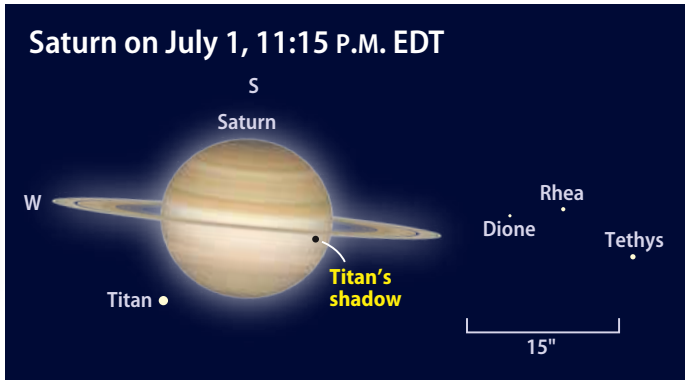
EVENING	MIDNIGHT	MORNING
Saturn (west)	Jupiter (southeast)	Mercury (northeast)
	Uranus (east)	Venus (east)
		Mars (east)
		Jupiter (southwest)
		Uranus (south)

Jupiter will reach opposition in August, so it currently presents a disk about as large as it can get. The giant planet spans 47" across its equator and 44" through its poles.

Any telescope will show two dark belts crossing Jupiter's disk, one on either side of the equator. During moments of steady seeing, several more dark belts appear. The region between the two equatorial belts rotates in 9 hours and 50 minutes; the rest of the planet takes 5 minutes longer. The resulting wind shear causes the turbulence visible in small telescopes. Look for dark spots and bright clouds, which can change location in as little as 10 minutes because the planet rotates so rapidly.

Jupiter has four bright moons that all orbit the planet in its equatorial plane. And Earth now lies in nearly the same plane. This means precise alignments can occur in which one Galilean moon occults or eclipses another. A few dozen such mutual satellite events take place this month, although an observer at a fixed location will see fewer than half.

For observers in North America, July's best eclipse occurs the morning of the 8th when Ganymede eclipses Io. Io starts to fade at 4:27 A.M. EDT. In 4 minutes, it dims nearly 90 percent, then recovers fully 4 minutes after that. The best occultation arrives the evening of July 30. Io occults Europa beginning at 11:21 P.M. EDT and ending 9 minutes later.



Titan's shadow crosses Saturn's northern hemisphere the evening of July 1. The shadow transit begins at 10:49 P.M. EDT and continues until well after Saturn sets. *Astronomy*: Roen Kelly

Neptune stays within 2° of Jupiter throughout July, and the pair will appear in a single wide-angle field through most telescopes. Both planets slide westward relative to the background stars this month, but Jupiter moves faster. As July begins, Neptune lies 0.7° northwest of Jupiter. On the 13th, Jupiter passes 0.6° due south of Neptune. Don't confuse Neptune with a brighter object, the 5th-magnitude star Mu Capricorni, which lies in the same field. Neptune glows at magnitude 7.8 and has a noticeable blue-gray hue.

A little more than an hour after Jupiter and Neptune rise, **Uranus** pokes above the horizon. At magnitude 5.8,

Comet search

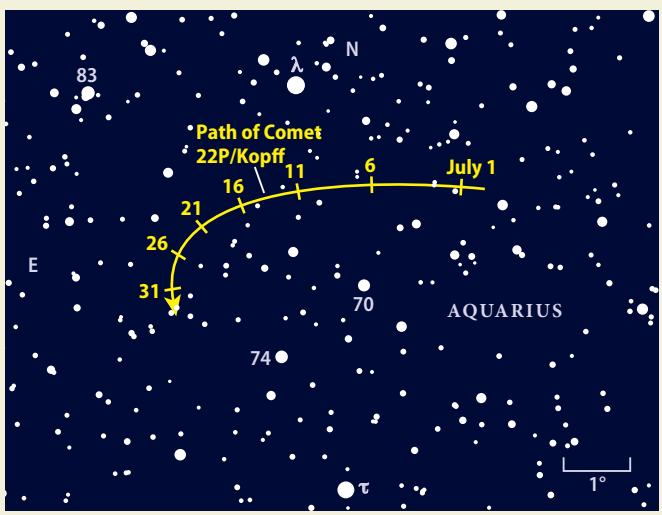
Comet Kopff swims through Aquarius

After spring's bright comet C/2007 N3 (Lulin), the inner solar system now returns to regular programming. You should be able to spot the 8th-magnitude periodic comet 22P/Kopff through binoculars from a dark site. The comet floats among the background stars of Aquarius, several degrees east of Jupiter and on best display after midnight. Although midnight may seem late to some people, Jupiter and Comet Kopff can make a perfect nightcap to a pleasant observing session among the treasures along the Milky Way's spine.

Solar radiation pressure always pushes comet dust away from the Sun. For Kopff, it sweeps the tail almost directly away from Earth, effectively hiding it behind the comet's head. The resulting circular glow should look diffuse at the edges because we're looking at it head-on instead of in profile, which would make the sunward edge stand out sharply. Still, Kopff lies far enough from the Sun (about 150 million miles) that its modest activity should not completely obscure the nearly pointlike false nucleus at the glow's center.

Something special could happen the weekend of July 25 and 26. We then will see the comet's orbit edge-on, so Kopff's fan-shaped tail appears like a line. The chance exists that the line will stick out enough on the sunward side to give the appearance of an anti-tail.

Comet Kopff's closest point to the Sun, called perihelion, lies just outside Mars' orbit. And like the outer planets, Kopff performs a retrograde loop when it's near opposition. The comet begins this loop as July ends, so you won't see much movement this month.



Comet 22P/Kopff should glow around 8th magnitude in July as it moves slowly through the background stars of Aquarius. *Astronomy*: Roen Kelly

If we're lucky, a second comet could rival Kopff in July's night sky. It all depends on whether solar radiation warms the icy nucleus of Comet C/2006 W3 (Christensen) enough to make it glow brighter than astronomers expect. You can find Christensen in the southeastern part of the constellation Cygnus.

Locating **asteroids**

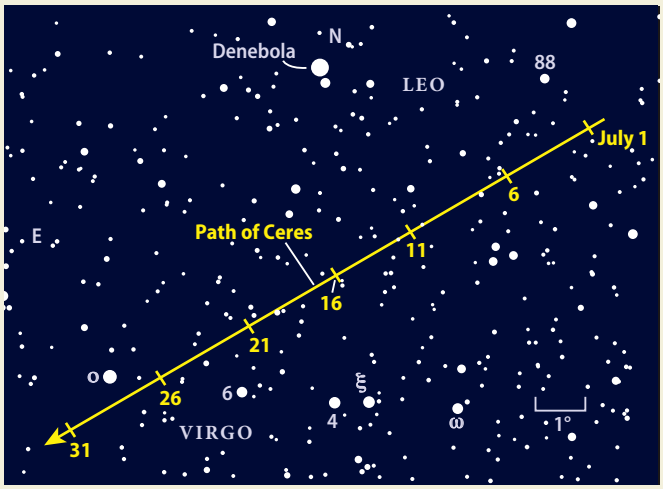
It's time to say "so long" to Ceres

Although its record-close approach happened earlier this year, Ceres remains at the top of our asteroid observing list. July is the last month to get a reasonable view of Ceres before it slides behind the Sun on the solar system's farside. At magnitude 8.8, it has faded two magnitudes since its February peak, yet the biggest asteroid remains easy to find with a small telescope from a suburban backyard.

The chart at right shows all background stars as bright as Ceres. This will help you identify the asteroid using basic pattern-shapes. If you're not sure which dot of light is Ceres, sketch the field including 4 or 5 stars, then come back in a night or two to see which one moved.

Start as evening twilight deepens. Ceres lies just south of the bright star Denebola at the tail of Leo the Lion. The two will appear in the same finder field. Remember that with an inverting finder scope, Ceres will be above rather than below Denebola.

On the evenings of July 28 and 29, Ceres lies less than 30' south of the 4th-magnitude star Omicron (o) Virginis. That's about the same amount of sky spanned by the Moon, so the star and asteroid will fit comfortably in the same field through a low-power eyepiece.



Ceres slides from Leo to Virgo this month, just a stone's throw south of the 2nd-magnitude star Denebola. Binoculars or a small telescope will show you the 9th-magnitude asteroid. *Astronomy*: Roen Kelly

Uranus shows up through binoculars after midnight, but it's tricky to find against the bland background of the constellation Pisces the Fish. First, locate the easternmost star in Pisces' well-known Circlet asterism, which lies below the Great Square of Pegasus. Then move 6° due south of this star, and you'll see a pair of "stars" — the northern one is Uranus; the southern target is a true star, 20 Piscium. The star shines slightly brighter than Uranus.

By the time Jupiter climbs to its peak in the south, both **Venus** and **Mars** have risen in the east. The stars of Taurus the Bull, along with its two bright star clusters, the Hyades and Pleiades (M45), form a spectacular backdrop to the morning planets. On the 1st, Mars stands 4° above Venus, and the two lie less than 10° to the Pleiades' right. Mars glows at magnitude 1.1 while Venus shines more than 100 times brighter, at magnitude –4.2.

Throughout July, Venus and Mars trek eastward across Taurus, with Venus moving at a faster pace. Venus lies 7° south of M45 July 4; Mars passes 5° below the cluster 1 week later. On July 13, Venus marks the northern tip of the V-shaped Hyades while the constellation's brightest star, Aldebaran, stands 3° away in its normal spot at the southern tip. Venus' presence radically changes the familiar appearance of Taurus.

A waning crescent Moon transforms the scene July 18. The Moon then lies 4° from both Mars and the Pleiades while Venus stands in central Taurus. The following morning, the Moon appears 6° to Venus' left. By July 27, Venus forms the southern horn of the Bull, less than a Moon's width north of the normal horn, Zeta (ζ) Tauri. That same morning, Mars lies 5° due north of Aldebaran, and the two look like near twins.

Through a telescope, Venus doesn't change much from one day to the next. Observe it once a week, however, and you'll notice a subtle difference. During July, Venus' apparent diameter shrinks from 19" to 15" while its phase fattens from 62 percent to 73 percent lit. Mars spans a mere 5" and shows no detail. The planet won't improve significantly until late autumn.

A diamond ring almost always highlights a total solar eclipse. The longest such eclipse this century takes place July 22 in eastern Asia and the western Pacific. Anthony Ayiomamitis

Half an hour before the Sun rises July 1, you might spot **Mercury** low in the east-northeast. It pierces the twilight because it shines brightly at magnitude –1.0. The innermost planet disappears within a few days, however, and won't return this month. It reaches superior conjunction with the Sun July 13.

The longest **total solar eclipse** of the century occurs July 22. The eclipse begins at sunrise in India, and from there the Moon's shadow zips across eastern Asia. The track crosses China for much of the morning before leaving the mainland near Shanghai.

Observers just south of this city will experience nearly 6 minutes of totality. The track then moves out over the Pacific Ocean. Maximum eclipse occurs about 195 miles east of Iwo Jima, where observers will see the Sun disappear for 6 minutes and 39 seconds. For more details, see "Get ready for the great Asian eclipse" on page 56.

Ask Astro

Astronomy's *experts from around the globe answer your cosmic questions.*

Could aliens image our solar system's planets?

Q: What would our solar system look like if aliens observed it with the same telescope used to image three planets around the star HR 8799? — Mark Jonathan Davis, Studio City, California

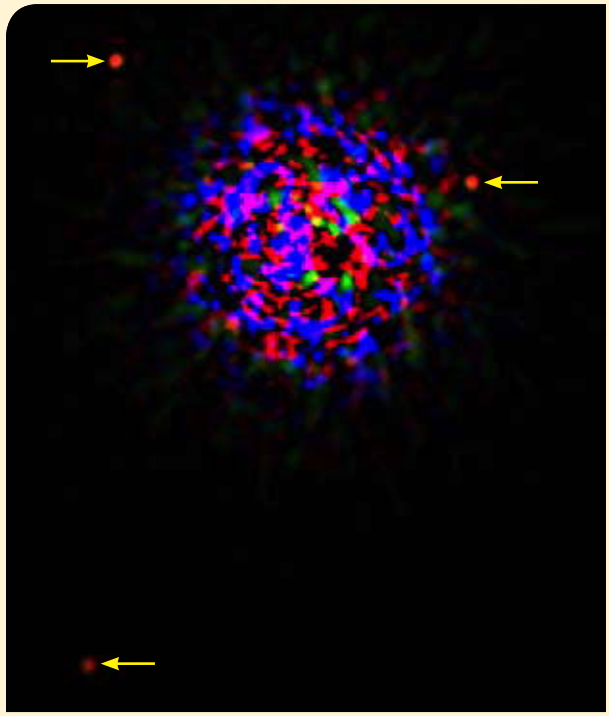
A: Astronomers imaged three planets around HR 8799 with the 8-meter Gemini North and 10-meter Keck telescopes in Hawaii. Infrared instruments picked up the heat emanating from three warm young planets. "Adaptive optics" technology canceled out some of the blurring caused by Earth's atmosphere.

If beings on an earthlike planet orbiting HR 8799 pointed one of these telescopes at us, they would see only the Sun. Our solar system's planets are much older, cooler, and smaller than those orbiting HR 8799. This means the telescopes would be blind to their infrared traces.

However, aliens could succeed with a different instrument. They would need to send the telescope into space and outfit it with a device called an occulter to block the Sun's obscuring glare. An occulter would make our planets stand out better against the background.

With these modifications, **aliens could image Venus, Earth, Jupiter, and Saturn. The scientists could also track the planets' orbits and collect spectroscopic data that would reveal Earth's water and oxygen as well as carbon dioxide on Venus and methane on Jupiter and Saturn.**

— Marc Kuchner, NASA's Goddard Space Flight Center, Greenbelt, Maryland



Three planets orbit the star HR 8799, as revealed by this infrared image. Hawaii's Keck and Gemini North telescopes zeroed in on the young planets' heat signatures to create the first group portrait of another solar system. Christian Marois/National Research Council Canada

MARTIAN MYSTERY

Q: How much water covered Mars' surface, and which areas had the most water? Why did it disappear? — Mark Frasch, Springfield, Pennsylvania

A: Scientists don't all agree on how much water existed on Mars and for how long. One view suggests oceans covered the lowlands on much of the Red Planet's northern hemisphere. The other extreme is a cold and dry Mars that never had standing water for more than a few weeks at a time — even during catastrophic outbursts that carved many of what we now see as dry riverbeds.

The majority opinion, however, is that in the first billion years of martian history, liquid water was at least intermittently released onto the surface of Mars. Furthermore, the water probably ponded in short-lived lakes in low plains and some crater floors, lasting for months or many years.

The evidence also suggests Mars possessed a denser atmosphere in its first billion years. This probably made Mars somewhat warmer and helped keep the water from evaporating as rapidly as it would in the planet's current climate.

Gradual climate change ended the Red Planet's wet phase. Mars' weak gravity allowed the atmosphere to leak into space molecule by molecule. Also, large asteroidal impacts were much more frequent in those days and could have blown much of the atmosphere into space. The climate grew colder, and the rest of the water probably soaked into the ground and froze, creating today's massive underground ice deposits.

Future science missions to Mars should help fill in the gaps in knowledge. The Mars Atmosphere and Volatile EvolutioN (MAVEN) mission, set to launch in 2013, will explore the history of the planet's atmosphere and climate. **— William K. Hartmann,** Planetary Science Institute, Tucson, Arizona

WHEN GALAXIES COLLIDE

Q: When galaxies merge, what happens to their central black holes? — **Ken Renner,** Navarre, Ohio

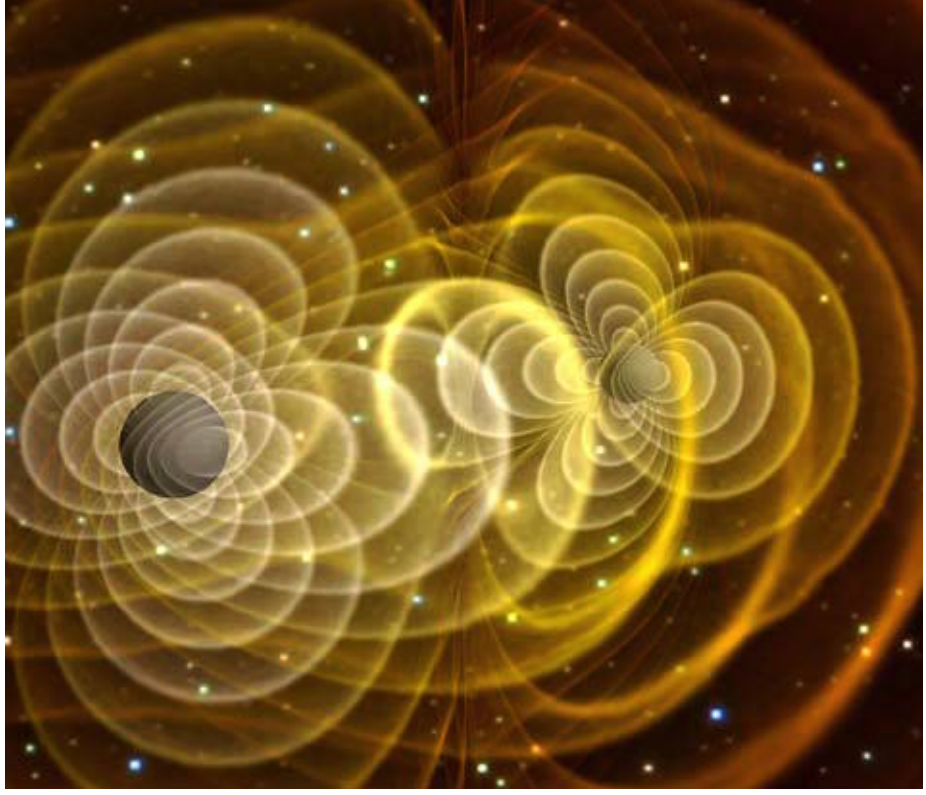
A: When galaxies merge, their central black holes combine to form a single, more massive black hole. But the merger process includes several dramatic events.

As the black holes approach each other, the tug of their powerful gravity on nearby stars can fling them across the galaxy. In extreme cases, such "hypervelocity" stars may slingshot completely out of the galaxy and into intergalactic space.

These encounters sap orbital energy from the black holes, which causes them to spiral ever closer to each other. As the black holes narrow the gap, they radiate a tremendous amount of gravitational energy. The so-called gravitational waves ripple through space-time for long distances. Indeed, astronomers hope to study black-hole mergers with special observatories that record the passing of gravitational waves.

The black holes also begin to whirl like gyroscopes. The disks of gas spiraling into them like whirlpools get stirred up, heated, and expelled from the immediate vicinity of the black holes. This creates a gap around them like the hole in a doughnut. Finally, the black holes merge, forming a single black hole.

Depending on how the spins combine, the merged black hole can fly away at up to 1 percent of light-speed. Theoretically, this violent crescendo of forces can fling the black hole to the outer reaches of the galaxy or even eject it entirely. — **Josh Faber,** Center for Computational Relativity and Gravitation, Rochester Institute of Technology, Rochester, New York



Chris Henze (NASA)

Two black holes merge in this computer-generated image based on a NASA simulation. As the black holes approach each other, their violent interaction generates ripples in the fabric of space-time.

CELESTIAL NAVIGATION

Q: Is there an equivalent to the North Star in the Southern Hemisphere? — **Justin Shaw,** Beaverton, Oregon

A: The star Sigma (σ) Octantis lies approximately overhead to an observer at Earth's South Pole, just as Polaris (the North Star) lies above the North Pole. **Solely based on its position, Sigma Octantis could be considered the "South Star," but, unlike Polaris, it is too dim to be a convenient celestial reference point for stargazers and navigators.**

At magnitude 2.0, Polaris is easily visible in the Northern Hemisphere. Stargazers use it to align their telescopes to the stellar coordinate system and find objects based on their distance above or below the celestial equator. Sailors in the Northern Hemisphere can also use Polaris to determine their latitudes.

Glowing dimly at magnitude 5.45, Sigma Octantis is just above the limit of naked-eye visibility for most people. As a result, the South Pole star is not useful for navigating either the sky or the oceans. — **Daniel Pendick,** Associate Editor

A+ Find out why the Moon sometimes looks so big: www.Astronomy.com/toc.

ASTROIMAGING SCIENCE

Q: Is it possible to combine digitized observations of an object from widely separated telescopes, creating a virtual interferometer? — **Robert Keeler,** Culver City, California

A: Digital interferometry is possible with low-frequency radio wavelengths, but not with light in the high-frequency optical portion of the spectrum.

To do interferometry, radio astronomers digitally record signals from multiple telescopes and then combine them later in a computer. As the individual radio signals add or subtract, they form a complex "interference" pattern. Astronomers then extract information from the pattern to create a more detailed view of the object being observed than any single radio telescope could produce on its own.

By contrast, optical interferometers must combine the actual light images from different telescopes and then measure certain key features in the resulting interference pattern. These instruments typically operate in the visible and near-infrared portions of the spectrum.

Unfortunately, the frequencies of visible and infrared light are tens of thousands of times higher than radio frequencies. The technology to record and combine such high-frequency optical signals doesn't exist. So, for now, optical interferometry is restricted to arrays of telescopes that can "see each other." — **Harold A. McAlister,** Georgia State University, Atlanta

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Astrophotography

Go deep for faint nebulae with astroimager Dean Salman

A dark sky, wide-field scope, and filtered CCD camera enables this Arizona skyshooter to capture distant HII regions in the Milky Way. **Text and images by Dean Salman**

Imagine me as a 10-year-old at a camp in the Southern California mountains curled up in a sleeping bag looking up at the night sky. As I viewed thousands of stars in the Milky Way, I asked myself, "What is really up there?" I spent the next 40 years trying to find the answer.

Even earlier, for a second-grade reading project, I chose a book called *The Sun*. Shortly after that, I built a miniature solar system for a science project. On my 12th birthday, my parents gave me my first telescope — a 2.4-inch (60 millimeters) refractor. When I looked at the sky, however, I couldn't see the same pictures I saw in the books. I wondered why.

My early astrophotography

Years later, I discovered photography with a camera on a tripod. After taking a 30-second exposure of the Milky Way, I was hooked. Two years later, I took my first shot through a telescope of the Orion Nebula (M42). When I examined the picture, I saw a faint wisp that I couldn't view with the same instrument.

For the next 30 years, I migrated from Kodak 103-AE black-and-white film to hypersensitized Kodak Technical Pan 2415. I finally settled on color slide film. In 2001, my friend Rockett Crawford loaned me his Santa Barbara Instrument Group ST-7 CCD camera. After my first 60-second shot of the Crab Nebula (M1), I left film behind.

The equipment I chose

When I ventured into imaging, I started with the brightest objects. I was amazed

— Continued on page 50

Dean Salman *photographs the sky from Tucson, Arizona. He has been sending his images to* Astronomy *since 1978.*

The Snake Nebula (Barnard 72) winds its way through the Milky Way in Ophiuchus. The nebula is about 0.25° long. The author combined 36 exposures totaling 90 minutes to create this image.

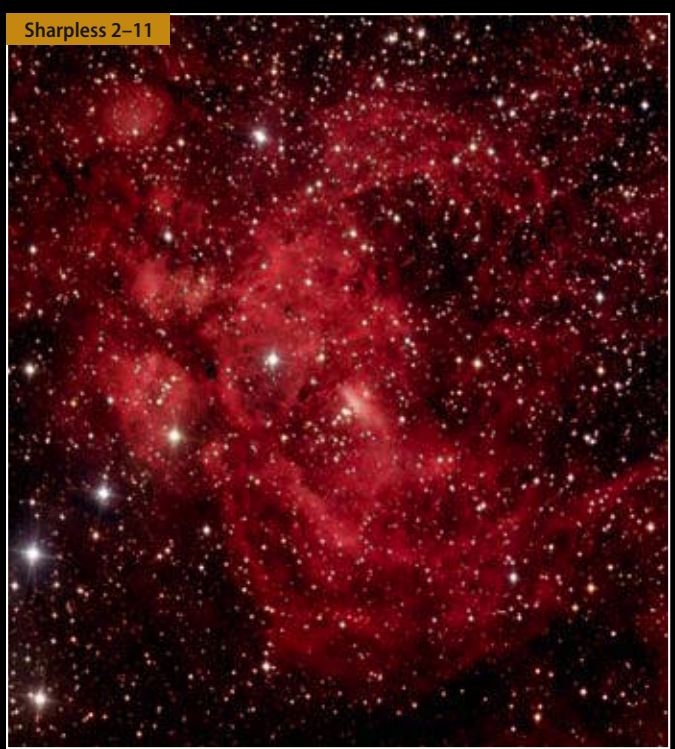
^ Emission nebula NGC 896 in Cassiopeia takes on a whole new appearance when imaged through a trio of narrowband filters. For this image, Salman assigned the color red to thirty 15-minute exposures through a Sulfur-II filter. He then let green represent forty 15-minute exposures through a Hydrogen-alpha filter. Finally, blue shows forty 15-minute exposures through an Oxygen-III filter. He stacked the images to produce the final picture.

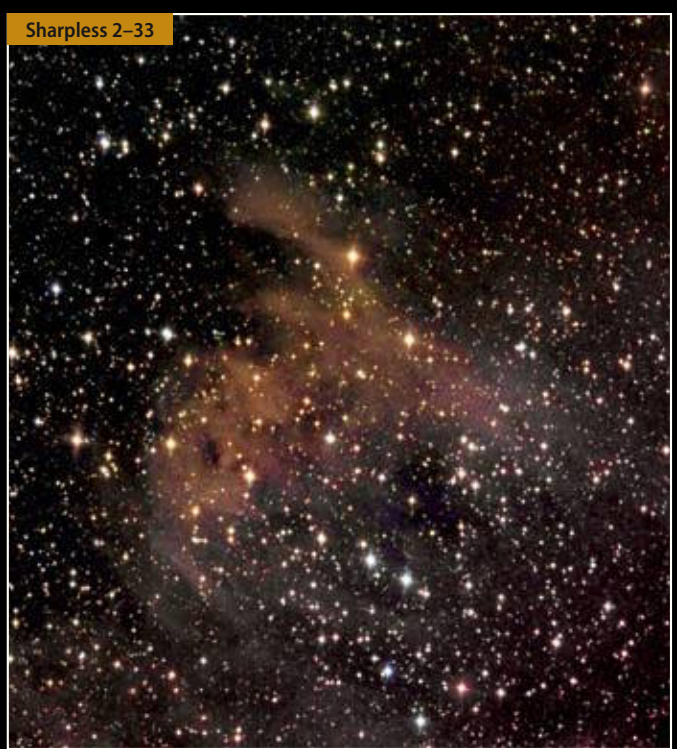
> Astroimager Dean Salman owns a roll-off roof observatory in Tucson, Arizona. His main imaging telescope is a 7.2-inch Takahashi Epsilon 180ED hyperbolic astrograph with a focal ratio of f/2.8.

Dean Salman's Sharpless Catalog project

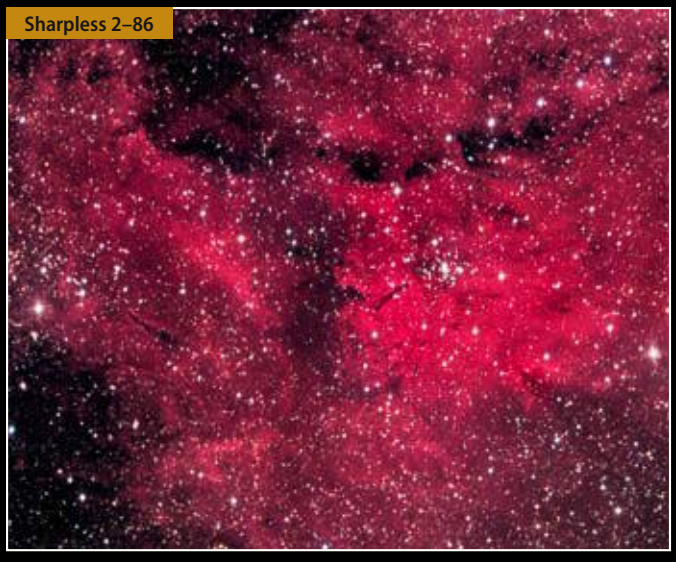
In 1959, American astronomer Stuart Sharpless published his second catalog of 313 ionized hydrogen regions. The author's goal is to image them all.

Sharpless 2–9


Sharpless 2–11


Sharpless 2–33

Sharpless 2–216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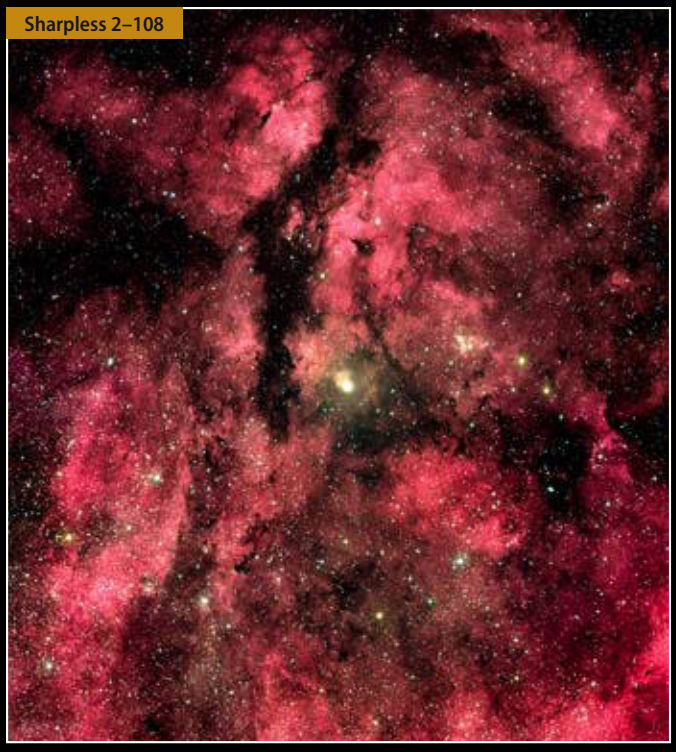

Sharpless 2–108

Sharpless 2–278

Sharpless 2–45

— *Continued from page 46*

at the details the CCD camera attached to my small telescope was picking up. I resolved galaxies millions of light-years away, something impossible with film.

As far back as my film days, the faint, sometimes wispy nebulae in the Sharpless Catalog intrigued me. These objects were almost impossible to pick up with film no matter how long the exposure. CCD cameras changed all that.

But even with sensitive cameras, the nebulae I shoot are so faint that it's not uncommon for an image to take a total of 12 to 16 hours of exposure time. Each is made up of many 15-minute exposures, which I later use software to stack.

Although I have imaged through many systems, my current setup is an Intes Micro 8-inch f/4 astrograph and an SBIG ST-10XME CCD camera. I have 10 filters. I use R(ed), G(reen), and B(lue) filters for standard color images and Oxygen-III and Hydrogen-alpha filters for higher contrast images.

The objects I target range in size from small galaxies 1' across to giant clusters that cover up to 10° of the sky. The shapes and structures these objects reveal still surprise me, and I always get excited to take new pictures.

My current project

The goal I have worked on during the past year, and that I continue to pursue, is to capture the 313 objects in the Sharpless Catalog. Because these nebulae glow as a result of ionized hydrogen, I use Hydrogen-alpha as my main filter to bring out fine details.

When I reviewed the more popular objects other amateur astronomers image, I decided to target a catalog that many photographers ignore. However, as I post my images on popular newsgroups, these objects are becoming more popular.

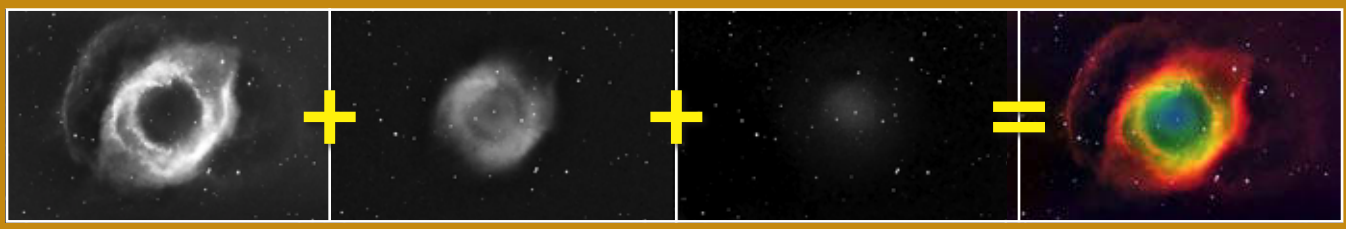
Thinking back on my days at camp, it's interesting how astronomy has changed. All of the new technologies have helped me fulfill my quest to see what's in the night sky, and I look forward to completing my Sharpless Catalog project so future astronomers may benefit from it.

Examine more Dean Salman Sharpless images on www.Astronomy.com/toc.

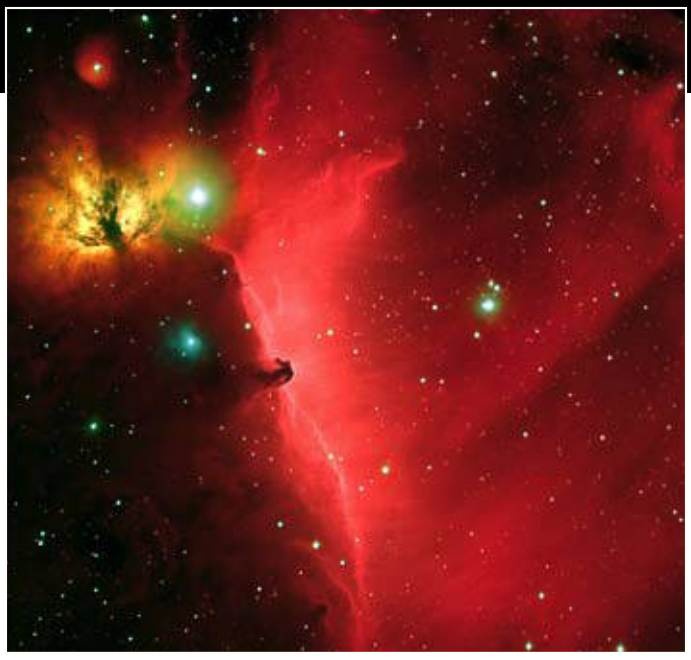
This image of the Andromeda Galaxy (M31) reveals dark dust lanes, both of M31's bright satellite galaxies, and reddish star-forming regions along the spiral arms. The author stacked twelve 10-minute and seventy-two 5-minute exposures (8 hours total) to generate this image.

Omega Centauri (NGC 5139) is the Milky Way's largest and brightest globular cluster. You'll find it 36° due south of Spica (Alpha [α] Virginis). The author's final exposure count was 21 — six with no filter, and five each through red, green, and blue filters. His total exposure time was 1 hour.

The North America Nebula (NGC 7000) and the Pelican Nebula (IC 5069–70) display many brightness variations in this false-color image. The author assigned red to exposures taken through a Sulfur-II filter, green to Hydrogen-alpha exposures, and blue to those taken through an Oxygen-III filter. It took 6 hours of exposure time to create this image.



This set of images shows what goes into producing a narrowband color image. The author shot exposures through Hydrogen-alpha, Oxygen-III, and Helium-II filters. He then assigned a color (red, green, or blue) to each filter and created a false-color image of the Helix Nebula (NGC 7293).



The Horsehead Nebula (B33) and the Flame Nebula (NGC 2024) appear in this false-color image. The author attached a Nikon 300mm f/2.8 lens to an SBIG ST-8XME CCD camera. He took thirty-six 5-minute exposures through an Hα filter and twelve 5-minute exposures through OIII and He-II filters.

The Owl Cluster (NGC 457) in Cassiopeia doesn't require a big scope. The author used an 8-inch Maksutov-Newtonian telescope at f/6 and an SBIG ST-2000XM CCD camera. He took six 3-minute exposures through red and green filters and nine 3-minute exposures through a blue filter.

Sharp-eyed observers can spot the magnitude 7.3 Sculptor Galaxy (NGC 253) with their naked eyes when it lies high in a dark sky. To capture details like the ones shown here, however, total exposure times creep into the hours, even with sensitive CCD cameras. To create this image, the author combined twelve 5-minute unfiltered exposures with ten 2-minute exposures through each of red, green, and blue filters.

Explore planetary nebulae in Cygnus

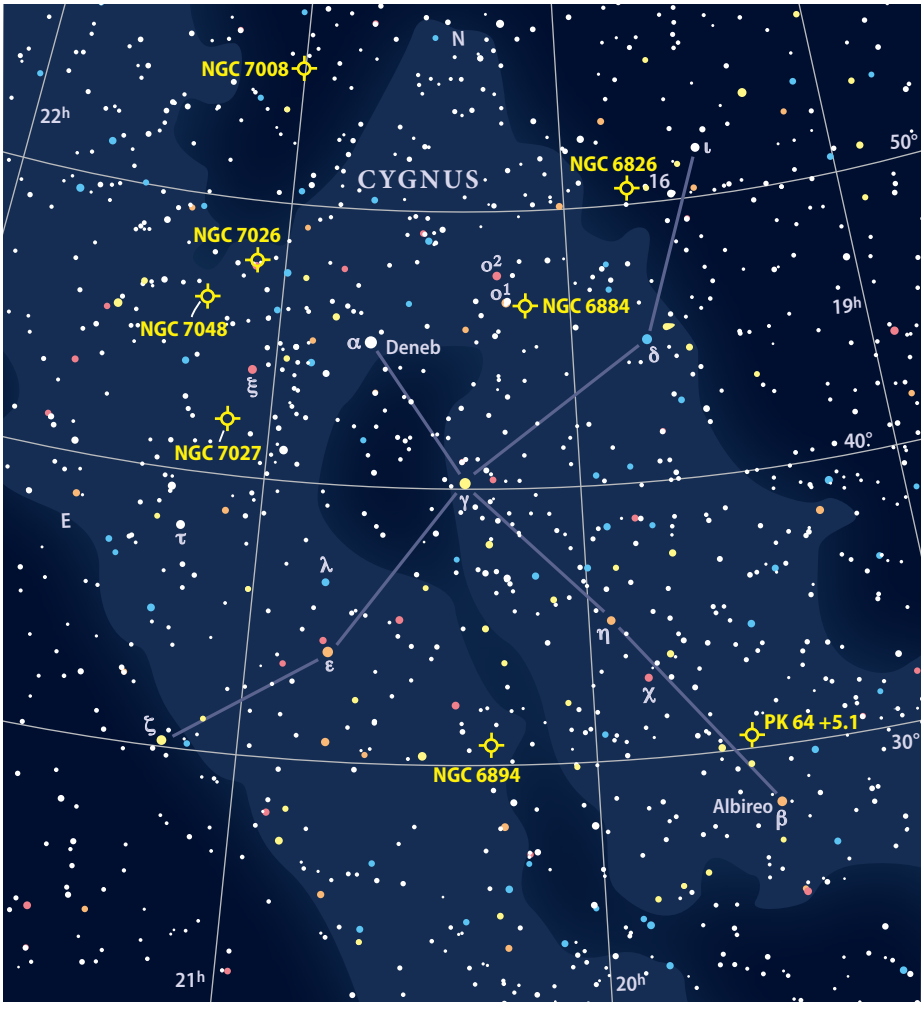
These dying stars offer colored rings, twisted filaments, and odd-shaped blobs. **by Phil Harrington**

Notice the filament structure inside NGC 6894's ring. The magnitude 14 star on the upper right of the nebula's ring gave this object the nickname the Diamond Ring Nebula. Adam Block/NOAO/AURA/NSF

The universe is full of strange and wonderful sights, but few can have the multiple personalities of planetary nebulae. As a low-mass star — less than 8 solar masses — goes through its death throes, its gravity collapses the core into a white dwarf. The star throws its outer shells of gas outward into space. To astronomers of the 18th and 19th centuries, many of these stars at the end of their evolution looked just like the small disks of the recently discovered planets Uranus and Neptune. William Herschel coined the term "planetary nebula," and even though they have no relation to planets, the name stuck.

Astronomers know of about 3,000 planetary nebulae scattered throughout the Milky Way. Some look like perfectly symmetrical disks. Others show bizarre distended shapes that were contorted by an outflowing particle wind from the precursor star, the gravity of companion stars, or perhaps the gravity of a family of orbiting planets.

This month, the constellation Cygnus brings some amazing planetary nebulae into view. Here are the best and the oddest of the bunch. How many can you see?



Plenty of planetary nebulae lie in Cygnus the Swan. Use this chart to maneuver your way through the sky to observe these eight objects. *Astronomy*: Roen Kelly

Realm of the normal

Let's begin with the most famous and brightest of Cygnus' planetary nebulae, the **Blinking Planetary** (NGC 6826). Look for it about ½° due east of the beautiful double star 16 Cygni.

This planetary's nickname comes from its habit of disappearing when viewed directly through smaller telescopes. You can clearly see the nebula's magnitude 10.6 central star, but the nebula is nowhere to be found. If you use averted vision — look off to one side to see the object out of the corner of your eye — the planetary pops into view as a uniform glow. That's because when the planetary nebula's delicate light falls on the less sensitive central part of your eye's retina, the central star's brightness overwhelms it. Averting your vision focuses the combined light along the retina's more sensitive edges, which brings both nebula and star into view.

At 212x, my 10-inch telescope shows that NGC 6826's distinctive bluish-green disk has a slightly brighter inner ring as

Phil Harrington *is a contributing editor of* Astronomy.

Donn and Aaron Starkey/Adam Block/NOAO/AURA/NSF

One of the more bizarre planetaries, NGC 7008 reminds many of a human fetus. The bright spots on the northern tip and at the western edge are regions of dense gas — not stars.

well as a dimmer outer halo. Ionized oxygen within the nebula causes the blue-green color, and gravity twists the expanding shell, resulting in the two-shell appearance.

Larger instruments operating at 300x or higher may also reveal mysterious knots of gas that look like "handles" at the outer edge of the planetary's major axis. These gaseous lobes, called Fast Low-Ionization Emission Regions, may represent subsequent bursts of matter flung outward from the star after the planetary nebula formed.

A far more challenging planetary lies 7½° southeast of NGC 6826, near a colorful little asterism that involves Omicron[1] (o[1]) Cygni. **NGC 6884** measures only about 6" across. When observing through my 8-inch reflector, I wrote that it's a "very small, faint disk at 210x; nearly stellar at 54x."

To spot small planetaries like NGC 6884, you may need to "blink" the nebula using a narrowband or Oxygen-III (OIII) filter. Center your telescope on the field containing NGC 6884, and hold your nebula filter between the eyepiece and your eye. Alternately move the filter in and out of the optical path to "blink" the planetary. Stars, which are broadband emission objects, will dim more noticeably than the planetary, which focuses its energy emissions in a narrow portion of the visible spectrum. Do this back and forth rapidly, checking each stellar point

Rich Jacobs

The Blinking Planetary (NGC 6826) doesn't actually "blink." Instead, this effect is a result of how we observe it. The central star's brightness drowns out the rest of the nebula with direct vision. To see the nebula, use your peripheral, or "averted," vision. Then as you move your eye, you'll see the nebula blink in and out of view.

NGC 7048 is a ringlike planetary nebula some 6,200 light-years distant. At higher powers, the ring structure appears to break up at certain points (visible here at the top and bottom).
Richard Robinson and Beverly Erdman/Adam Block/NOAO/AURA/NSF

NGC 7027 is in the beginning stages of a planetary nebula, and the central star has yet to blow away the dust cloud. Once the star does so, NGC 7027 should look similar to a glowing ring.
Donn and Aaron Starkey/Adam Block/NOAO/AURA/NSF

as you go, and the planetary will have no choice but to reveal itself.

Although it's a little fainter than our last target, **NGC 6894** strikes me as being much more obvious. At 360x with an OIII filter in place, my 10-inch scope shows a nearly perfectly circular disk with a noticeably darker center. Look closely. You'll notice that a 14th-magnitude star sits on the nebula's northwestern edge. That chance alignment gives NGC 6894 its nickname, the Diamond Ring Nebula. Look for the Diamond Ring about halfway between Albireo (Beta [β] Cygni) and Epsilon (ε) Cygni.

The odd ones

A surprisingly bright planetary is located about 2½° north of Albireo, but few people have ever seen it. In 1893, American astronomer William Campbell discovered this unusual starlike object at Lick Observatory. Studying its spectrum, Campbell could tell immediately that, despite the object's starlike appearance, he was not seeing an ordinary star. Instead, he had spotted an uncharted planetary nebula.

The 10th-magnitude central star of **Campbell's Star** (PK 64+5.1) completely overpowers the tiny 7.5" disk at low and medium powers. At 200x, my 4-inch refractor shows the nebula's subtle glow surrounding the star, but only after studying it intently with averted vision. I find little benefit by blinking the nebula with either a narrowband or an OIII filter, even through a telescope with twice the aperture. A Hydrogen-beta filter moderately improves the view, noted northern California observer Steve Gottlieb suggested.

Campbell's Star may look more like a point than a planetary, but there is no mistaking **NGC 7027** when viewed with 100x or more. Its bluish-green disk spans 10" by 5" and appears elongated northeast-southwest in my 8-inch scope. But the view through larger double-digit apertures shows just how odd this object is. My 18-inch cranked up to 300x reveals a faint outer halo surrounding a brighter, oddly rectangular interior divided into two lobes. Look for NGC 7027 about 1¾° south-southeast of Xi (ξ) Cygni.

NGC 7026 lies nearby. Through double-digit apertures, NGC 7026's oval disk shows two brighter sections on either side of a dimmer central rift that runs north-south along the major axis. This unusual appearance has led to the Cheeseburger Nebula nickname. An OIII filter makes an ideal condiment to accentuate the burger. NGC 7026 is a bipolar planetary nebula. Comprising about 10 percent of the population, bipolar planetaries have two gaseous lobes that expand away from a common center.

Next let's head about 6° east-northeast of Deneb (Alpha [α] Cygni) to find **NGC 7048**. My 10-inch reflector shows a faint grayish disk next to a 10th-magnitude field star. Magnifying the scene to 254x reveals a noticeably uneven texture to the planetary, with its soft edges looking somewhat fan-shaped. A faint star superimposed on its northwestern edge is not the planetary's antecedent star. The true central star, shining at 19th magnitude, is nowhere to be found.

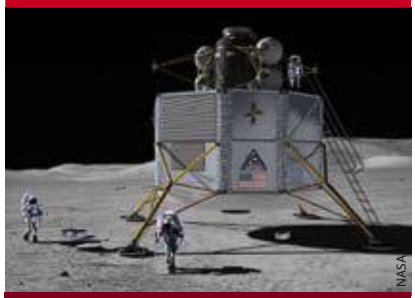
We close our tour with one of my favorites. Nestled near Cygnus' northern border is **NGC 7008**, a truly bizarre sight that reminds most observers of a coat button, a comma, an ear, or even a human fetus. Adding to the intrigue is the double star h 1606, which lies superimposed on the nebula's tapered southern tip. Eighteen arcseconds separate its stars, which shine at magnitudes 9.3 and 10.2 and glow with subtle tints of blue and gold.

Look carefully. You should also see that brighter regions pepper NGC 7008. One of those "lumps" is the nebula's off-center central star, a 13th-magnitude point slightly offset toward the west. A dark wedge protrudes into the nebula just east of the central star, which causes the weird fetus shape. A second "star" lies at the northern tip of the nebula, directly opposite the double star, while a third can be seen along the eastern edge. Although both of these regions appear stellar, studies reveal them to be condensed knots of nebulosity.

These are but a few of the wondrously weird sights that await you in Cygnus.

Visit www.Astronomy.com/toc for a table of all planetary nebulae in Cygnus.

NEXT MONTH
in the August issue



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Get ready for the great Asian eclipse

The century's longest total solar eclipse promises to thrill those who stand in the Moon's shadow. **by Richard Talcott**

Tunç Tezel

Baily's beads show up as the last few glimmers of sunlight before totality begins — or the first glimmers after totality — as the Sun's disk shines through deep valleys along the Moon's limb.

Like two cars speeding toward the same intersection in some action thriller, the Sun and Moon are racing relentlessly toward the same spot in the sky. But there will be no screeching brakes, twisted metal, or fiery explosion. When the two worlds reach their date with destiny, more than 94 million miles (151 million kilometers) of empty space will separate them. Neither will experience anything out of the ordinary.

The same won't be true for Earth. When the Sun and Moon align July 22, 2009, a cone of darkness will cut a narrow course through eastern Asia and the western Pacific, turning day to night and rewarding anyone who stands in the path with a sight they'll never forget.

The Moon's dark void will block the Sun's brilliant disk for several precious moments. Flaming-red solar prominences and ghostly coronal streamers will poke above the Moon's pitch-black limb. The amazing show will last up to 6 minutes and 39 seconds, making this the longest total solar eclipse of the 21st century.

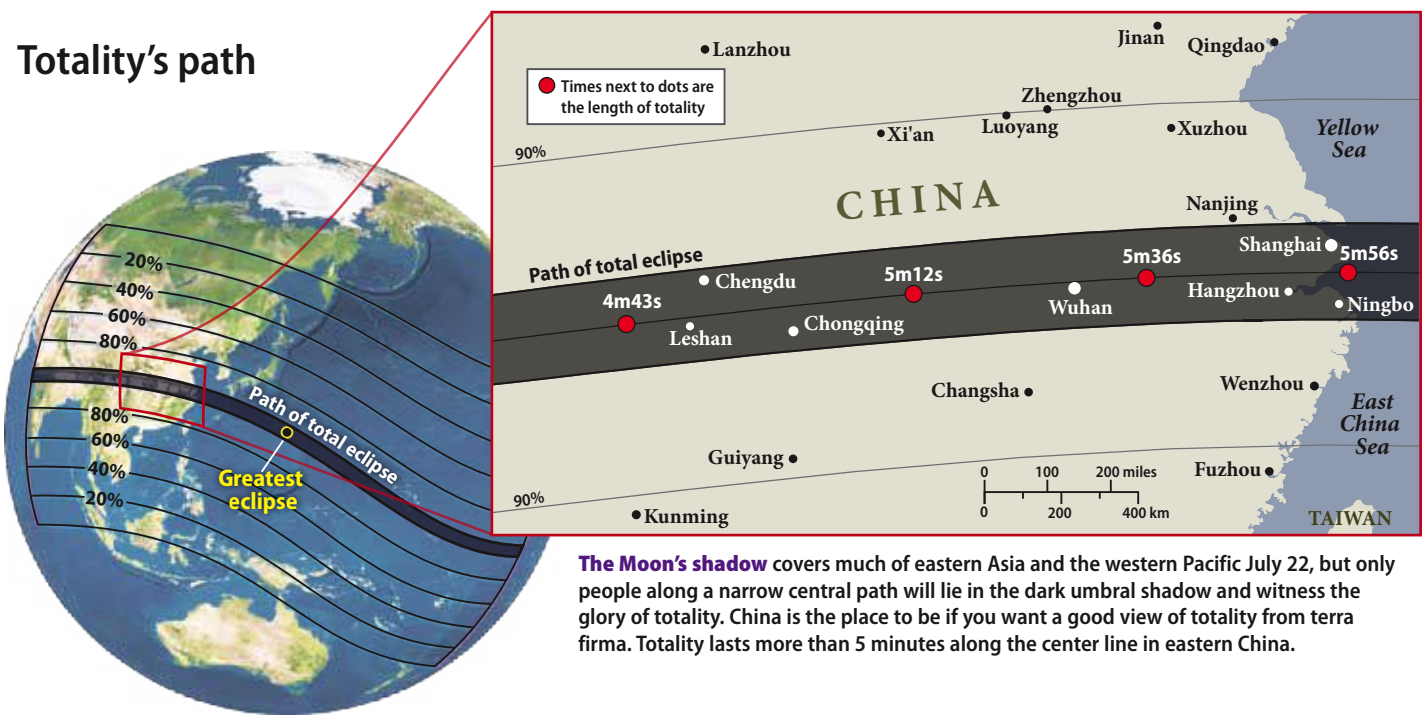
First contact: India

The dark inner part of the Moon's shadow, called the umbra, is the region under which eclipse watchers can see totality. It first touches Earth's surface at daybreak just off India's west coast, north of Mumbai, and then races to the east-northeast. The shadow traverses India in only 6 minutes, yet it brings more than 3 minutes of totality to anyone on the center line. Some of the large cities in the path include Surat, Indore, Bhopal, and Patna.

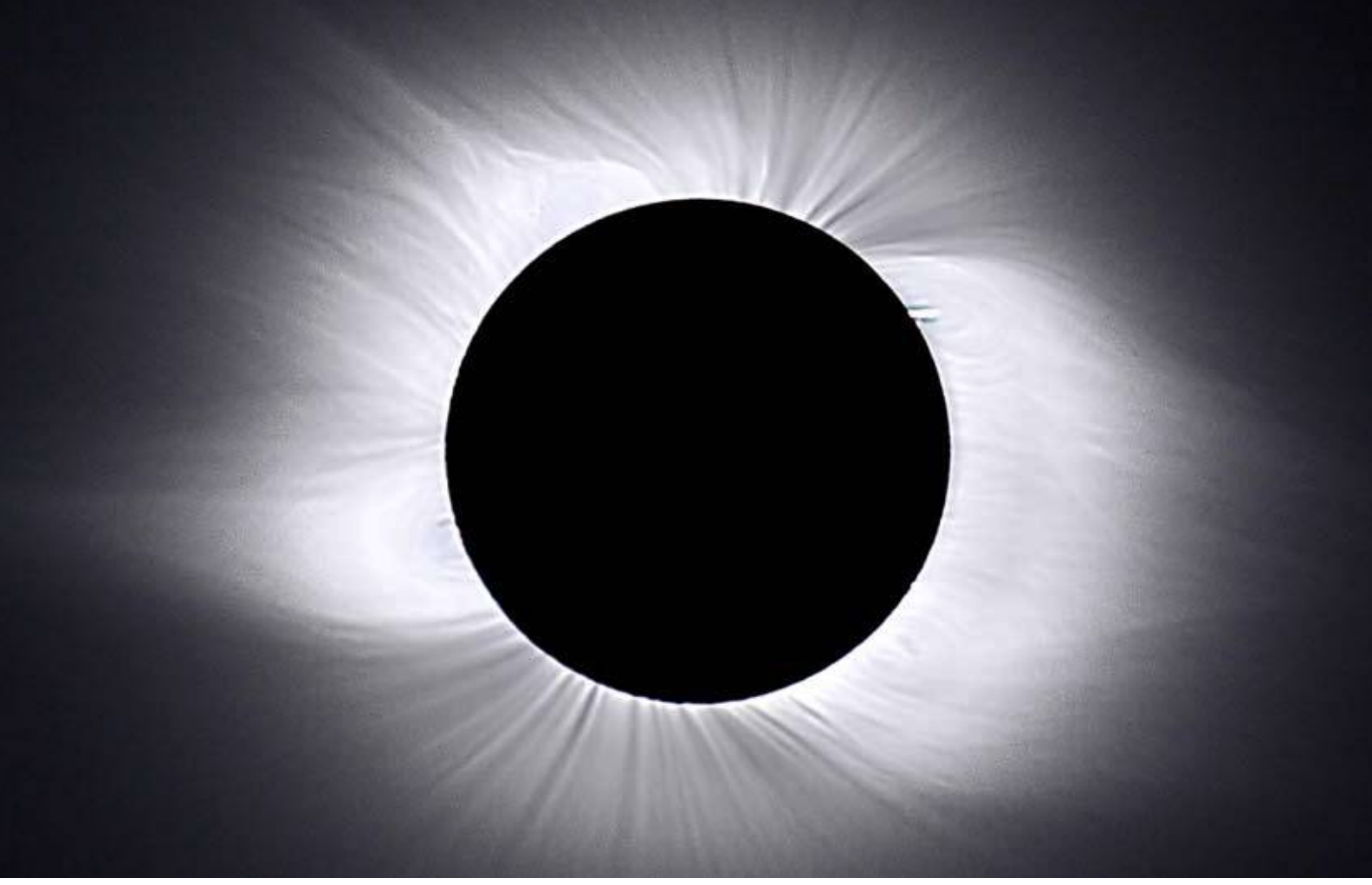
Although lots of people live in the path of totality, it's unlikely that many will see the eclipse. The monsoon season is at its height in India during July, so sunny skies are scarce. Low pressure over India draws in warm, moist air from the Arabian Sea and the Indian Ocean.

Measurements from satellite data show the best prospects lie near Patna — although even there average cloudiness

Totality's path



The Moon's shadow covers much of eastern Asia and the western Pacific July 22, but only people along a narrow central path will lie in the dark umbral shadow and witness the glory of totality. China is the place to be if you want a good view of totality from terra firma. Totality lasts more than 5 minutes along the center line in eastern China.



The Sun's corona shows lots of streamers at solar minimum. The Sun's cycle was at a low ebb during the August 1, 2008, eclipse seen here. Astronomers expect similar conditions in July. Anthony Ayiomamitis

approaches 65 percent. Statistics show that this number climbs above 80 percent in many other parts of the country.

After India, the center line crosses Bhutan and then enters the eastern Indian states of Arunachal Pradesh and Assam. The umbral shadow is so big here (about 140 miles [225 km] wide), however, that people in parts of Nepal, Bangladesh, and Burma also will experience totality. Unfortunately, the weather prospects again remain dismal.

A land of dynasties

The situation improves noticeably after the shadow crosses the rugged mountains separating India and China. In Sichuan province, residents of the capital city of Chengdu will experience 3 minutes and 16 seconds of totality, and those in Chongqing increase that to 4 minutes and 6 seconds. On the center line between these two cities, the Sun will disappear for nearly 5 minutes.

Farther east, China's fourth-largest city, Wuhan (with nearly 10 million inhabitants), lies just 12 miles (20 km) from the center line. It will be bathed in darkness for 5 minutes and 25 seconds with the eclipsed Sun halfway to the zenith.

The shadow crosses China in 35 minutes, reaching the coast at 9:40 A.M. local time. (All of China lies in one time zone, which runs 8 hours ahead of Universal Time and 12 hours ahead of Eastern Daylight Time.) China's largest city, Shanghai (with nearly 20 million people), receives 5 minutes of totality. People on the center line 41 miles (66 km) south of the city can expect 5 minutes and 55 seconds under the eclipsed Sun.

Weather prospects across China easily exceed those in India, but they aren't as high as they've been for many recent eclipses. China has its own monsoon season during July. Warm, moist air flows in from Southeast Asia and the South China Sea and meets cooler, drier air funneling in from the north. Across most of China, satellite measurements show an average cloudiness between 50 and 60 percent.

Remember that these numbers are for a stationary observer. Stay mobile and your odds improve dramatically. Areas near Wuhan look particularly good for those who want to be inland. Although sites along the coast have a slightly better chance of sunny skies, they also suffer from lots more haze and air pollution.

Like a gleaming solitaire, a diamond ring announces the end of an eclipse's partial phases and the onset of totality. James Manning

Richard Talcott *is a senior editor of* Astronomy. *He is the author of* Teach Yourself Visually Astronomy *(Wiley Publishing, 2008).*

The July 22, 2009, eclipse shares a sisterhood with the eclipse of July 11, 1991. Both belong to saros number 136, a saros currently delivering the longest total solar eclipses to eager shadow chasers. Michael Stecker

A déjà vu eclipse

Long solar eclipses, like the one on July 22, 2009, don't happen frequently. The last one to approach 7 minutes of totality brought darkness to Hawaii, Mexico, and Central America July 11, 1991. These two eclipses share more than great length, however. If you look at this pair closely, you'll find that the Sun and Moon appear in the same general area of sky and near the same points in their orbits and that the eclipse tracks follow similar latitudes.

The similarities are more than random coincidence. The 1991 and 2009 eclipses belong to the same "saros" — a period of 6,585.32 days — in which eclipses repeat with remarkably similar geometries. The extra 0.32 day means successive eclipses occur about one-third of the way around the world to the west of the previous one.

The 2009 eclipse is the 37th member of saros number 136. Many observers got their first taste of eclipse chasing with the 36th member in 1991. Still others remember the June 30, 1973, eclipse in Africa, the last one to bring more than 7 minutes of totality. Member 32 of this saros (which occurred May 29, 1919) holds a special place in science history. During totality, British astronomer Arthur Eddington measured the positions of several stars near the Sun. He found the positions were offset from their normal places because the Sun's gravity bent the stars' light. It provided strong evidence for Einstein's then-new general theory of relativity. — *R. T.*

You should keep two other weather factors in mind before heading to China. First, July is typhoon season in the western Pacific. These storms — the Pacific equivalent of Atlantic hurricanes — can spread thick clouds well inland and pretty much rule out any escape from beneath them. At this time of year, Shanghai experiences an average of one typhoon every 20 years.

Second, the tropical conditions in China are far more oppressive than most North American and European travelers have experienced. Average highs hover around 90° Fahrenheit (32° Celsius) and average lows around 75° F (24° C), with nearly constant high humidity.

After leaving the Chinese mainland, the umbral shadow crosses the East China Sea. Its next landfall is in Japan's Ryukyu Islands and then, some 30 minutes later, the remote islands of Iwo Jima and Kitaio Jima.

Maximum eclipse occurs about 195 miles (315 km) east of Iwo Jima. At the peak, the Sun lies nearly overhead and disappears for 6 minutes and 39 seconds. Cruise ships offer the best option because clouds tend to build up on the islands and mobility is always advantageous.

Although the shadow's traverse of Earth's surface is only half over, the rest of the path lies over mostly open water. All told, the umbral shadow spends 3 hours and 25 minutes on the surface and crosses about 9,400 miles (15,150 km).

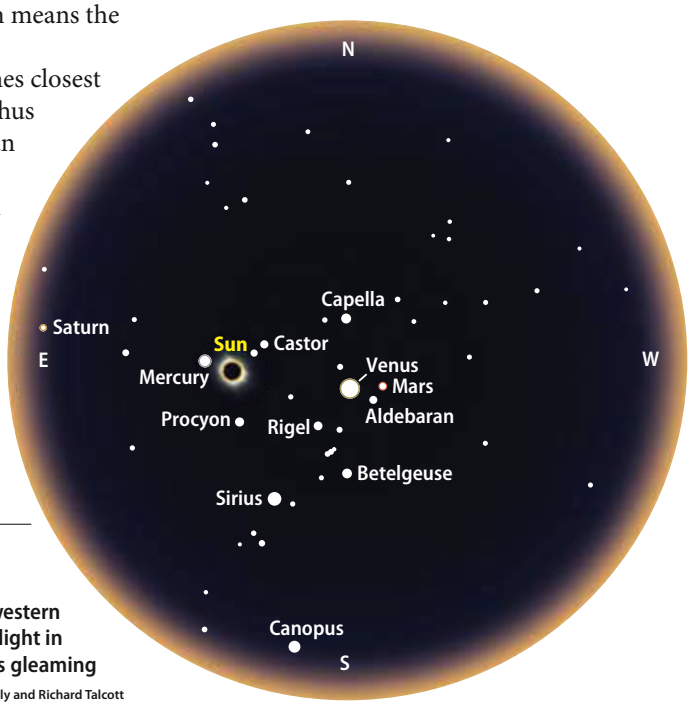
When worlds align

What makes this the longest total solar eclipse of the 21st century? Several factors contribute, but two stand out. First, the Sun is at its farthest point from Earth July 4. By July 22, the Sun hasn't come much closer, so it appears near its smallest in our sky. A small Sun means the Moon can cover it longer.

Second, the Moon comes closest to Earth for 2009 — and thus appears biggest — less than 5 hours before the eclipse begins. Just as a small Sun lengthens an eclipse, a large Moon covers the Sun longer. The Sun and Moon normally appear about the same size in our sky. At maximum eclipse July 22, the Moon appears 6.2 percent bigger.

On the big day

To get the most from viewing a total solar eclipse, arrive at your site at least an hour before first contact, when the Moon first touches the Sun's disk. This will give you plenty of time to set up equipment. A word to the wise: If this is your first total eclipse, keep it simple. Don't try to photograph the eclipse. The few minutes of totality will fly by, and you don't want to spend them fiddling with a camera. If you



The stars of northern winter will appear prominent during totality, when the Sun lies in western Cancer. The brightest point of light in the sky, however, will be Venus gleaming nearly overhead. *Astronomy*: Roen Kelly and Richard Talcott

^ Multiple images capture the hours-long progression of an eclipse from partial to total and back to partial phases. This sequence records the eclipse of July 11, 1991, which had nearly 7 minutes of totality. William Sterne

> Two huge solar prominences arced above the Moon's limb during the 1991 eclipse. That eclipse occurred near solar maximum, however, so this July's eclipse (near solar minimum) likely will feature fewer signs of an active Sun. Daniel Good

>> The domes of Mauna Kea in Hawaii made a picture-perfect foreground for the July 11, 1991, eclipse — the last total eclipse longer than the one this July. Barney Magrath

find totality exhilarating, you'll be back for more. That's the time for photography.

You don't need anything more than your eyes to get wonderful views of totality, although binoculars offer a convenient way to get a quick and more-detailed view. Unless you've seen several eclipses, leave your large telescope at home. Such instruments rarely reward the effort of lugging them halfway around the world, and if you have to move at the last minute as clouds threaten, they'll be useless.

During the eclipse's partial phases, eye safety is paramount. Sunlight can quickly and painlessly damage the eye's retina. For a direct view of the Sun, use only an approved solar filter or a #14 welder's glass. Most eclipse expeditions will supply "eclipse glasses" for safe viewing.

It takes a little more than an hour from first to second contact, when the eclipse becomes total. You won't notice much during the first half-hour. After the Moon blocks more than half of the Sun, however, start watching for subtle changes on Earth. Shadows will appear sharper as the light source in the sky grows smaller.

By the time the Moon covers about 80 percent of the Sun, the sky has grown noticeably darker and colors seem more vibrant. Look at sunlight filtering through the leaves of trees or bushes. You could see hundreds or even thousands of solar crescents projected by the tiny gaps between leaves.

With a minute to go before totality, the solar crescent dwindles to a thin sliver. Eventually, the crescent starts to break up as mountains along the Moon's limb poke through it. Known as Baily's beads, this string of pearls shrinks as the Moon continues its relentless march. Finally, just a single bead remains — the glorious diamond ring.

Totality arrives at second contact, when the Moon extinguishes the diamond ring. Now's the time to remove solar filters from your eyes, binoculars, telescope, and camera. Examine the totally eclipsed Sun with whatever equipment you have.

After your eyes adjust to the sudden darkness, the Sun's corona takes center stage. The corona's ghostly glow appears pearly white and likely will extend for a few solar diameters. Watch for delicate loops, swirls, and streamers. The corona's size and shape vary from one eclipse to the next. If the low levels of solar activity in early 2009 continue into July, expect an asymmetric corona with lots of streamers.

Also watch for reddish prominences arcing from the Sun's surface. You'll likely see them shortly after totality starts and shortly before it ends; at mid-eclipse, the large Moon probably will block them.

The long totality gives you time to check out your surroundings. Notice the sky's color and the twilight hues that ring the horizon. You should also see the brightest stars and planets. From China, Venus will be blazing almost directly overhead. Bright Mercury will lie slightly east of the Sun, and Sirius will glow about halfway up in the south-southeast.

Totality ends when the eclipse's second diamond ring appears, this one opposite the first's location. That's the signal to replace all your filters. The sequence of partial phases now plays out in reverse, although the main show has ended. This is a great time to view those effects you might have missed before totality, such as the multitude of crescents beneath a tree.

As soon as totality ends, people will start thinking about their next chance to witness totality. It won't be long. On July 11, 2010, the Moon will block the Sun completely along a path through the South Pacific. At maximum, the Sun will be hidden for 5 minutes and 20 seconds. Sounds pretty good to me.

Evening Stars
by David H. Levy

The Bard and astronomy

William Shakespeare composed many plays that reference rare astronomical events.

More than 4 centuries ago, in 1572, an 8-year-old English lad named William Shakespeare probably saw something peculiar in the sky. We don't know this for sure, but how could he have possibly missed it? All of a sudden a great star, more brilliant than Venus, burst into the night sky. Far away from Stratford, England, in Denmark, Tycho Brahe saw the new star and was so impressed that he allegedly asked a neighbor if he was dreaming.

We have no way of knowing if our language's greatest writer ever saw the 1572 supernova or the one that followed in 1604, but we do know that the night sky played a big role in his later writing. If astronomical historian Peter Usher is right, Shakespeare might have written about the supernova in the earliest lines of *Hamlet*:

Last night of all,
When yond same star that's westward from the pole
Had made his course to illume that part of heaven
Where now it burns …
(Shakespeare, *Hamlet* 1.1.35–39)

During the coldest months of the year, the supernova would indeed have appeared to shine between the North Star and the western horizon.

We also know that Shakespeare was familiar with an English forerunner to the telescope. He wrote about this device, called a "perspective glass," at the opening of *Richard II*:

For sorrow's eye, glazed with blinding tears,
Divides one thing entire to many objects.
Like perspectives which, rightly gazed upon,
Show nothing but confusion — eyed awry,
Distinguish form.
(Shakespeare, *Richard II* 2.2.16–19)

This is the Cobbe portrait of William Shakespeare (believed to be the only portrait painted from life). It will be on display by the Shakespeare Birthplace Trust in an exhibition titled "Shakespeare Found," from April 23 to September 6 at Shakespeare's Birthplace in Stratford-Upon-Avon, England. Image reproduced by agreement between The Shakespeare Birthplace Trust and the copyright holders.

When an observer looks at this perspective glass directly, the objects behind are blurred and indistinct. But when looking with a sharp angle, which acts as a sort of eyepiece, the view comes into focus. I have experimented with these views using one of my own telescopes. Using a perspective lens is like trying to use a regular telescope without its eyepiece. It is awkward, but if you hold your eye at a particular position above and at an angle to where the eyepiece is ("eyes awry"), then you can "distinguish form" to the starry background.

If these examples, written in poetic blank verse, aren't enough to convince, then Gloucester's lines in *King Lear*, written in simple prose, should do the trick. Because Shakespeare penned these lines around 1605, he may have been thinking of the unique pair of eclipses that darkened London in the fall of 1605.

During my lectures, I often poll audiences about how many solar, then lunar, eclipses they have seen. I also ask how many of one type would be followed by the other type just 2 weeks later, seen from the same location. It's pretty rare. (In early November 2003, my wife Wendee and I saw a total lunar eclipse from Montreal, but to catch the solar equivalent 2 weeks later, we had to travel literally to the end of the Earth — Antarctica.)

Shakespeare devotes almost two pages of *King Lear* to a discussion about eclipses that darkened London in 1605. A partial eclipse of the Moon, during which the shadow of Earth covered almost half the Moon, occurred in the predawn hours of September 27, and an almost total solar eclipse took place 2 weeks later on October 12. Gloucester begins, "These late eclipses in the sun and moon portend no good to us." Edmund argues: "This is the excellent foppery of the world, that when we are sick in fortune — often the surfeits of our own behavior — we make guilty of our disasters the sun, the moon, and the stars, as if we were villains on necessity."

Shakespeare had a broad interest in the natural events occurring around him. He seemed especially interested in eclipses, comets, novae, and meteors — those celestial objects that are part of the magnificent darkness that comes each evening with the night sky.

Observing Basics

by Glenn Chaple

Solar safety

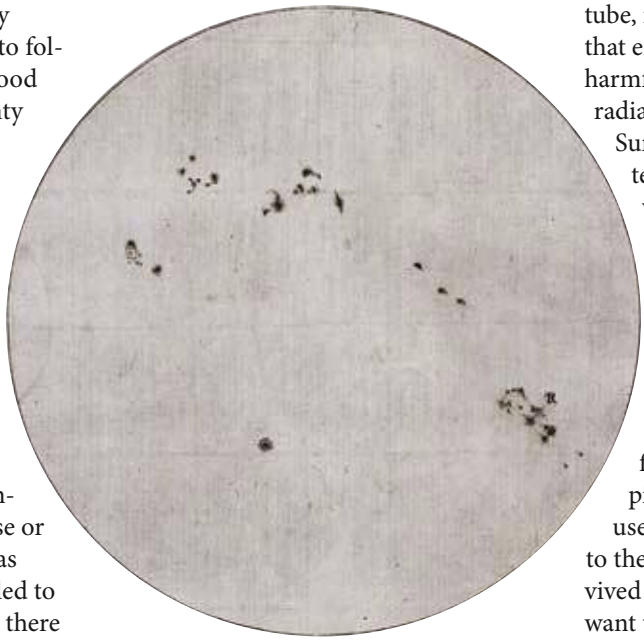
Repeat Galileo's observations of the Sun, but be sure to protect your eyes and eyepieces.

When I was growing up, my mother admonished me to follow three guidelines of good health: Eat my vegetables, get plenty of sleep, and never, ever look directly at the Sun with my telescope! OK, I made that up, but we astronomers need to take good care of those essential observing tools — our eyes. And eye safety is especially important when it comes to solar observing.

When writing about the consequences of viewing the Sun directly with a telescope, I used to relate the story of Galileo, who conducted solar observations at sunrise or sunset when the Sun's brilliance was reduced. Supposedly, the practice led to Galileo's blindness later in life. But there is compelling evidence that the story isn't accurate. According to research by scholars such as Andrew T. Young, an adjunct faculty member of San Diego State University's astronomy department, Galileo's late-life blindness was most likely a result of cataracts brought on by complications from rheumatoid disease.

Whatever the cause of Galileo's blindness, I would never recommend looking directly at the Sun with or without a telescope — not when it's rising or setting, and not even when it's veiled by a thick haze. Fortunately for Galileo, he soon learned that he could use a telescope to project the Sun's image onto a sheet of paper.

Four centuries later, solar projection remains a primary way to view our home star. After placing a low-power eyepiece in your telescope and aiming at the Sun (use the telescope's shadow, *not* the finder scope), hold a sheet of white paper about a foot from the eyepiece. Focus the projection until the circle of light (the Sun's disk) appears sharp at the edges.



Galileo sketched sunspots (such as this one from June 29, 1613) by projecting the Sun's image through a telescope onto a white card. He used these observations to prove the Sun was not a perfect heavenly body. Today, solar projection remains a common way to examine our star.

Linda Hall Library of Science, Engineering and Technology

Sun projection may not threaten your vision, but it puts your telescope — particularly the eyepiece — at risk. Don't use an expensive eyepiece. The adhesive holding the elements together could "cook," ruining the eyepiece.

At one time, I suggested using a simple, inexpensive 20mm Huygenian for the purpose. Several summers ago, I was projecting the Sun with such an eyepiece only to discover that the concentrated solar heat had melted part of one of the eyepiece's plastic components (the field stop)! Solar projection is still a recommended method for viewing the Sun. Just be sure to use a spare eyepiece.

For eye (and eyepiece) safety, try a solar filter. Secured to the front of the tube, it reduces the amount of sunlight that enters the telescope and filters out harmful ultraviolet and near-infrared radiation, which allows you to view the Sun directly and safely. Solar filters tend to be pricey — running anywhere from $30 to $180, depending on the supplier and size needed to fit your telescope. There are many reliable suppliers, including Thousand Oaks, Orion, and Celestron.

Many inexpensive telescopes manufactured in the latter half of the 20th century came with solar filters that screwed into the eyepiece. I always warn people not to use such filters, as they can shatter due to the buildup of solar heat. If you've survived a near-mishap with such a filter, I want to know. Please, first-person accounts only. I don't want to hear about your third cousin's best friend whose barber knows someone whose screw-in solar filter cracked during use.

By using the appropriate equipment, you can repeat Galileo's historic sunspot observations. The great astronomer discovered that sunspots are a transient phenomenon, appearing suddenly and then just as abruptly fading away. He correctly noted that they are surface features concentrated in a zone centered on the Sun's equator. Long-lasting sunspots led to a rough determination of the Sun's rotation, which Galileo equated to be the length of a lunar month.

As you try some sunspot observations of your own, please remember: Never, ever look directly at the Sun with your telescope! Oh, and yes, be sure to eat your vegetables, and get plenty of sleep.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: We look at the first double star and embark on an exciting International Year of Astronomy project. Clear skies!

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Astrodon
Orangevale, California

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[t] 916.712.2559
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Explore Scientific
Laguna Hills, California

Explore Scientific's 1¼" 6.7mm 82° Series Eyepiece combines low-dispersion and high-refractive-index optical glass. All optical surfaces are multicoated, and the internal surfaces are flat black. Eye relief is 14mm. The eyepiece weighs 10.9 ounces (310g).
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[t] 888.599.7597
[w] www.explorescientific.com

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[t] 916.671.5735
[w] www.farpointastro.com

Wooden eyepiece case
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Pinckney, Michigan

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[t] 734.347.1913
[w] www.wood-wonders.com

Electronic sky-meter reader
Knightware
Cary, North Carolina

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[w] www.knightware.biz

Broadband nebula filter
Garrett Optical
Tulsa, Oklahoma

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[t] 888.629.2011
[w] www.garrettoptical.com

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[t] 800.426.3089
[w] www.swarovskioptik.com

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Quantum Scientific Imaging
Dana Point, California

Quantum Scientific Imaging's replacement Series 500 filter wheel allows you to have another set of five filters ready to swap into your QSI Series 500 CCD camera.
Price: $199 (filters not included)
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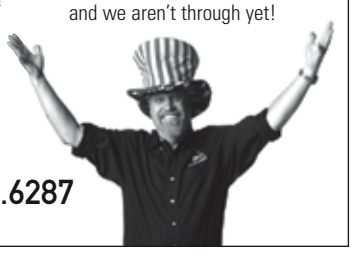

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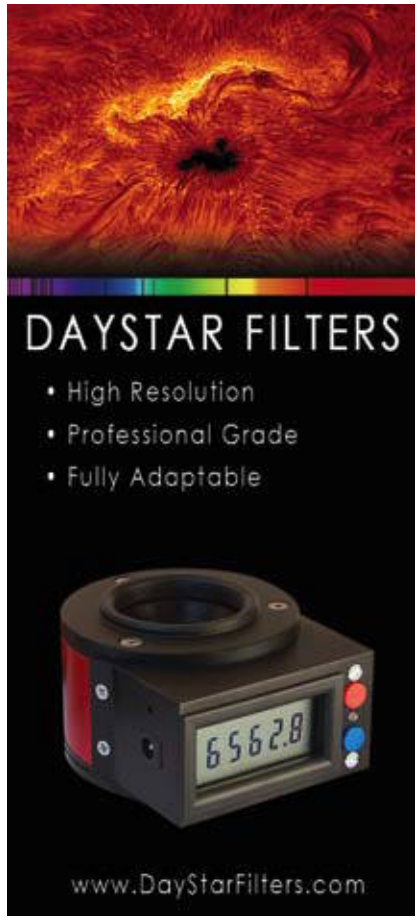

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by Michael E. Bakich

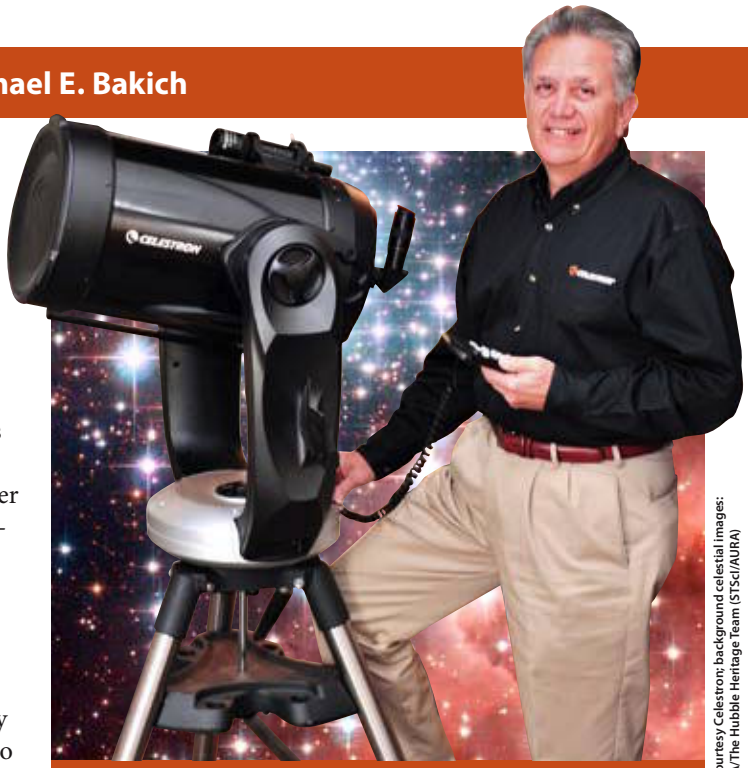
Joseph A. **Lupica**

President, Celestron

Joe Lupica joined Celestron's senior management team in June 1987. Starting in 1998, he led the company through the 4 years Tasco owned it. He and several other investors purchased Celestron in 2002.

In 2005, Lupica and his partners sold the company to another group of investors led by David Shen, the owner of Synta Technology Corporation in China. Together, Shen and Lupica helped Celestron develop a structure that offers consumers optical products with more features at lower prices.

Lupica's strong financial background created a culture that allows the development of new products while also improving the company's profitability. Celestron has not only significantly increased its market share over the past several years, but it also is financially stronger than at any time in its history.



Joe Lupica often shows celestial sights to others through Celestron's CPC 1100 GPS (XLT) telescope.

Portrait courtesy Celestron; background celestial images: NASA/ESA/The Hubble Heritage Team (STScI/AURA)

Tell us about your most popular models.

In 1987, Celestron introduced the first computerized telescope, the Compustar 14. Since then, we have focused on "ease of use" telescopes. Two lines are the most popular — the NexStar SE family and the CPC family. The NexStar SE family offers portable telescopes with features of more expensive models. The 4-inch model weighs only 21 pounds but includes a fully computerized operating system. The CPC family offers quick and simple alignment, GPS technology, and a stable mounting system for astrophotography.

Tell me something cool about Celestron.

Celestron will celebrate its 50th anniversary next year. During those years, it's had five groups of owners, but, throughout, Celestron has maintained a consistent company culture. One reason is that the company's founder, Tom Johnson, has remained a consultant since he sold Celestron in 1980.

I have consulted Tom many times during the past 20 years. In the business world, I think some companies fail to see the benefits of maintaining relationships with their founders and focus too closely on short-term goals.

How has Celestron changed through the years?

During our first 30 years, we were primarily a manufacturer and engineering design company. In the past decade, we redefined our core competencies as engineering design and sales/marketing. We recommitted the company to developing products — such as the CGE Pro Mount — for serious astronomers by maintaining a staff of eight full-time engineers. We also are generating lower price-point products to attract consumers into the hobby. One long-term objective is to make more people aware of how easy and entertaining stargazing is.

Do you enjoy observing?

I get the most enjoyment when I observe in groups. I have a home in the desert, and I enjoy taking out either the 8-inch NexStar SE or the 11-inch CPC to observe.

The 8-inch is so portable that I can start observing quickly. I have to admit, though, that my family and neighbors love when I set up the CPC. It is hard to beat viewing through an 11-inch scope on a desert night.

Can you share anything about upcoming products?

If I discuss new products, it would put undue pressure on our engineering department to meet our aggressive deadlines. That being said, it is important for Celestron to design products that "wow" serious astronomers as well as general consumers.

Astroimaging has become easier, but no company offers all components or is partnering with other companies to offer all components necessary to take great images. Celestron will achieve this goal within the next couple of years. We also will offer telescopes for first-time buyers that will allow them to enjoy observing at a reasonable cost.

Where, in your opinion, is the hobby headed?

We have a golden opportunity this year to increase our hobby's popularity. The United Nations declared 2009 as the International Year of Astronomy, which will give us an opportunity to attract a wider audience. We have a breadth of products to offer the people that become aware of our hobby through the IYA. Although we are in challenging economic times, the future appears bright.

"The United Nations declared 2009 as the International Year of Astronomy, which will give us an opportunity to attract a wider audience."

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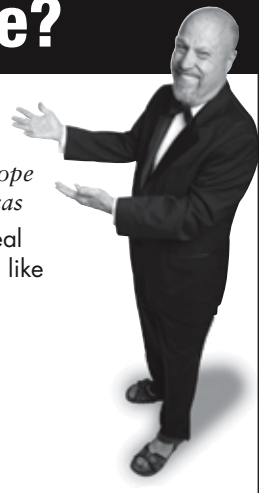

I was extremely pleased with the pre-sales technical support. — CB, Germany

My very highest praises for good old fashioned telescope business, a great rarity indeed these days. — CG, Texas

It was really great to have the opportunity to see a real telescope shop. I was blown away. We have nothing like this in our neck of the woods. — RP, New Zealand

….your packaging was excellent and so the scope arrived without any damage. — MD, Oregon

I love the way your web site is setup. It's like having total alignment with just one star. — OC, Michigan

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The 8" Astro-Tech R-C is only $1395. Are you as surprised as the competition?

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Ritchey-Chrétien astrographs used to cost a fortune. For some reason, R-Cs from other manufacturers still do.

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The 6" *2009 Hot Product* **Astro-Tech AT6RC**, ideal for imaging with DSLRs and Deep Sky Imager-type cameras, is **$795**.

And the 12" **Astro-Tech AT12RC** is only **$4495**. Another manufacturer's 12.5" R-C costs well over $20,000. For the price of that 12.5" scope, you could buy the 12" Astro-Tech and still have enough cash left over to buy a $15,000 compact car to carry it.

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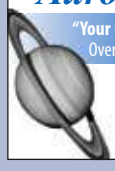
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The Cosmic Grid

All things high, low, weird, and wonderful in astronomy and space science. **by Daniel Pendick**

WEIRD

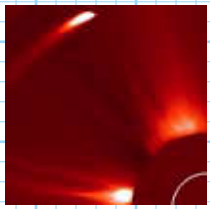
HOT

NOT

PREDICTABLE

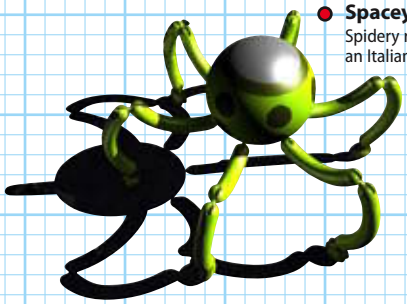
Dress warmly
British engineering students launch four Teddy Bears to nearly 100,000 feet on a balloon to test insulating spacesuits designed by school kids. The bear with the warmest tummy wins!

A snowball far from home
Comet 96P/Machholz 1 could be an escapee from another star solar system. Travel time: 1 billion years.



Sweet tweets from Mars
JPL media rep Veronica McGregor text-messages "tweets" from the Phoenix Lander. On discovering water ice, Phoenix exclaims: "wOOt! Best day ever!"

Spacey spiders
Spidery robot designed by an Italian team competes for the Google Lunar X-Prize. Check out that sporty athletic-shoe color scheme.



Mars in a jar
Danish scientists simulate martian soil in a stainless steel tank and discover that Earth bacteria could infect the Red Planet.

So refreshing
The space station's new water recovery plant almost makes drinking recycled urine sound exciting. Almost.

Earth calling
Twentieth Century Fox beams its tedious remake of *The Day the Earth Stood Still* to Alpha Centauri, the nearest star after the Sun.

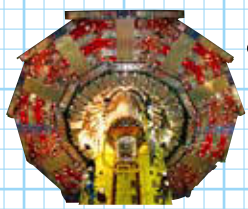
Bring lots of reading material
To those four hardy Europeans who competed for the chance to spend 105 days locked inside a Mars mission simulator, we salute you.

Spaceship dream
Blue Origin's Goddard experimental spacecraft lifts off and lands on its feet — just like in our favorite sci-fi movies.

Take me past your new leader
NASA hails to the new chief during the inaugural parade.

Special delivery
Russia's space agency RosCosmos offers $4,000 to compensate a Siberian shepherd after space junk falls on his land.

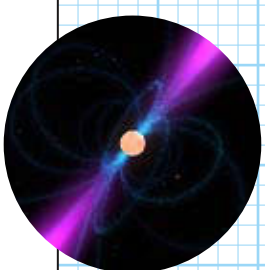
This space junk fell in Texas.



Weakest link
A faulty solder connection shuts down the $6.4 billion Large Hadron Collider after 9 days.

O brave new metaphor
Press-release writers who make scientists say they've found the "Rosetta Stone" that will help them solve [fill in favorite unsolved scientific mystery here].

Rhymes with hemorrhoid?
Plutoid: the International Astronomical Union's tag for bright icy non-planets beyond Neptune. Quick! Somebody call a poet!



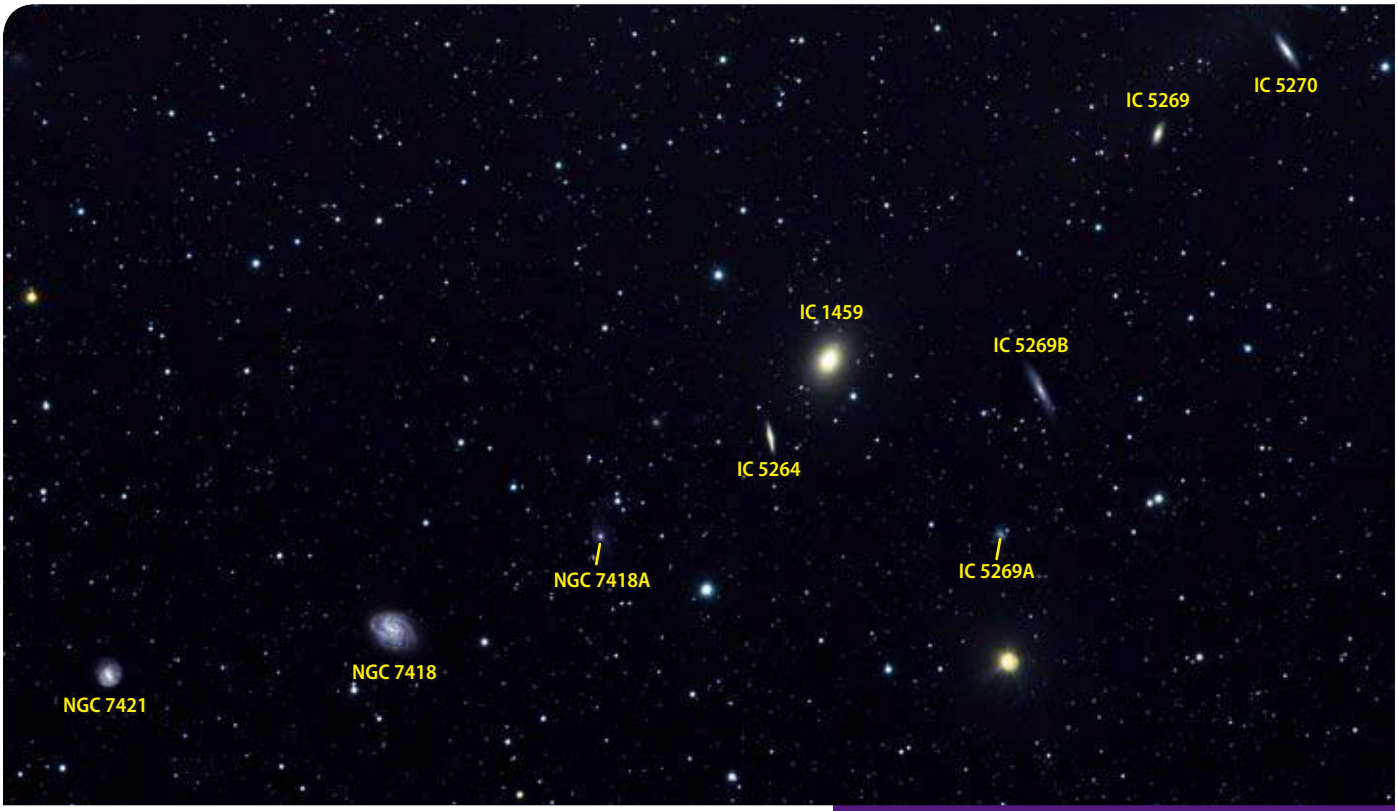
You can set your watch by it
Pulsar J1903+0327 spews lighthouse beams of radiation as it spins 465 times PER SECOND.

Let's hear it for science literacy
Paris Hilton says she fears being caught in a time warp during a planned space tourism flight.

See you in 2011
NASA delays the Mars Science Laboratory rover launch for 2 years because of glitch-plagued hardware made by a single company.

Photographs: Cambridge University Spaceflight (teddy bears); SOHO/LASCO (ESA & NASA) (comet); NASA/JPL-Caltech/UA (tweets); Team Italia (spider); Marslab/University of Aarhus (Mars in a jar); NASA/MSFC (urine); ESA (simulated Mars mission); NASA (Alpha Centauri); NASA (space junk); CERN/Michael Hoch (Large Hadron Collider); NASA/JPL-Caltech (Mars Science Lab); AP Images (Paris Hilton); NASA (pulsar); NASA/JPL-Caltech (plutoid); NASA (inaugural); Blue Origin (Goddard)

reader gallery



The IC 1459 galaxy cluster (6-inch Astro-Physics Starfire EDF apochromatic refractor at f/7.5, Finger Lakes Instruments ProLine 11002 CCD camera, LRGB image with exposures of 140, 30, 30, and 30 minutes, respectively) • Michael Sidonio, Googong, New South Wales, Australia

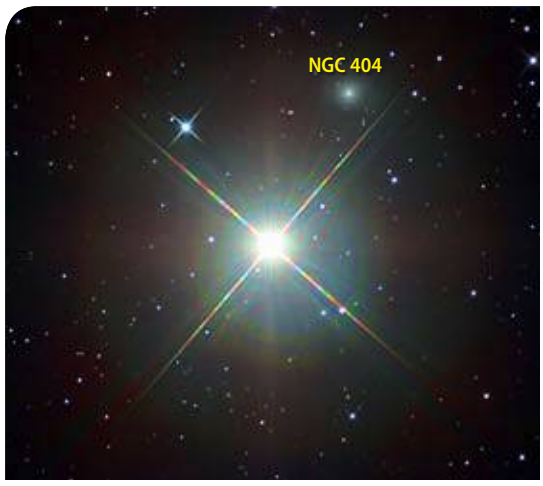
Comet C/2007 N3 (Lulin) shone near 7th magnitude in central Libra at the end of January. (10-inch Zen Baker-Schmidt telescope at f/3, SBIG STL-6303E CCD camera, LRGB image with exposures of 5, 1, 1, and 1 minutes, respectively, taken January 30, 2009, at 4h30m UT) • Paolo Candy, Cimini Astronomical Observatory, Italy

Portrait of a cosmic family

At the border of the southern constellations Grus and Piscis Austrinus lies the IC 1459 galaxy cluster, sometimes called the Grus chain of galaxies. It lies roughly 108 million light-years away. The object that lends its name to the group, giant elliptical galaxy IC 1459, shines brightest at magnitude 10.0. It measures 5.2' by 3.8'. The beautiful spiral galaxy NGC 7418 sits below and to the left of IC 1459. It measures 3.5' by 2.6'. IC 1459 is the prototype galaxy for a group whose members have a fast counterrotating core, and within it exists a giant black hole with a mass between 100 million and 400 million Suns.

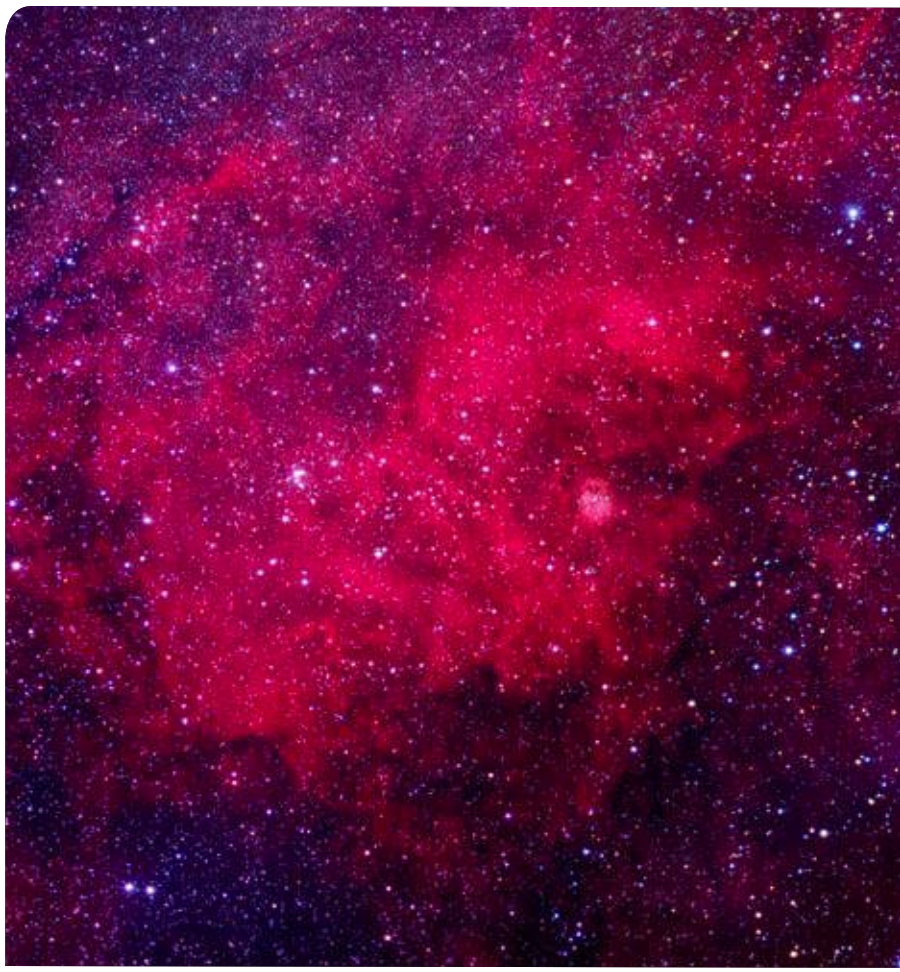
< The Rosette Nebula (NGC 2237–9) in Monoceros looks different through the "Hubble palette" of filters — Sulfur-II, Hydrogen-alpha, and Oxygen-III. (10-inch Takahashi BRC-250 Baker Ritchey-Chrétien telescope at f/5, FLI Proline 16803 CCD camera, SII/Hα/OIII image with exposures of 6, 5.5, and 5.5 hours, respectively) • Larry Van Vleet, Denver

V Mirach's Ghost (NGC 404) in Andromeda got its common name because it lies less than 7' north-northwest of 2nd-magnitude Mirach (Beta [β] Andromedae). This position makes NGC 404 tough to see. (6.4-inch Astro-Physics AP 160 StarFire EDF refractor at f/7.5, SBIG ST-2000XM CCD camera, LRGB image with exposures of 60, 30, 30, and 30 minutes, respectively) • Anthony Ayiomamitis, Athens, Greece



^ Reflection nebula IC 446 in Monoceros lies a bit more than 9° east-northeast of Betelgeuse (Alpha [α] Orionis). (10-inch Takahashi BRC-250 Baker Ritchey-Chrétien telescope at f/5, FLI ProLine 16803 CCD camera, RGB image all exposures of 50 minutes) • Giovanni Benintende, Castel di Judica, Italy

> NGC 6604 is an open cluster with emission nebulosity in Serpens. If you observe this combination object through a telescope, you'll need to use a nebula filter (like an Oxygen-III) to cut the stars' brightnesses and accentuate the nebula. (7.2-inch Takahashi Epsilon 180ED hyperbolic astrograph at f/2.8, SBIG ST-10XME CCD camera, Hα/RGB image with exposures of 60, 20, 20, and 20 minutes, respectively) • Daniel B. Phillips, Oceanside, California



reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.

This image of BBWo 56 in the southern constellation Puppis may be the first by an amateur astronomer. It is entry 56 in *The velocity field of the outer Galaxy in the Southern Hemisphere. I - Catalogue of nebulous objects* (1986) by Brand, Blitz, and Wouterloot. The region features both red emission and dusty reflection nebulosity. (6.2-inch Astro-Physics 155 EDF apochromatic refractor at f/5.4, Finger Lakes Instruments KAF-16803 CCD camera. LHαRGB image with exposures of 430, 160, 100, 100, and 100 minutes, respectively) • Thomas V. Davis, Inkom, Idaho

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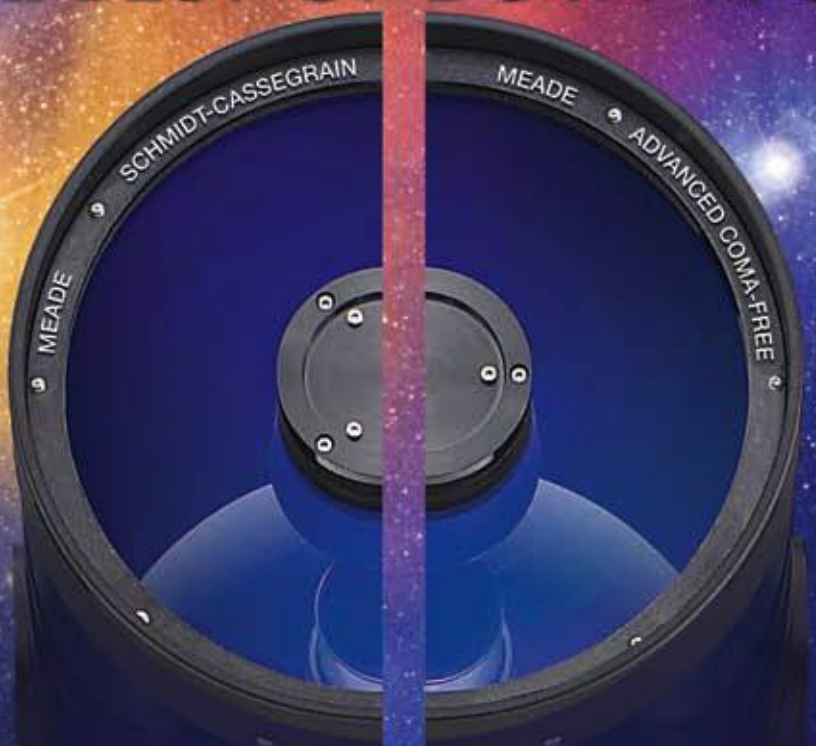

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